

# Zygote Quarterly: an open-source bio- inspired design journal

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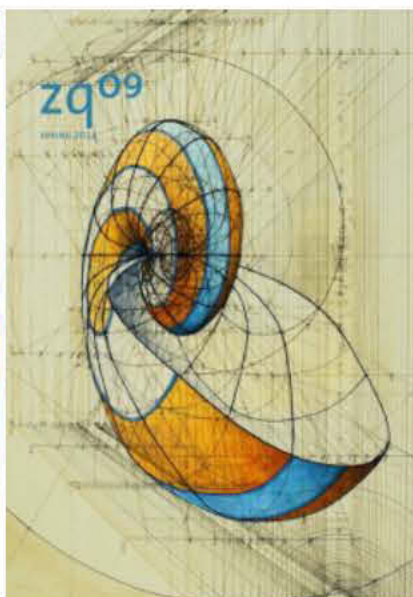
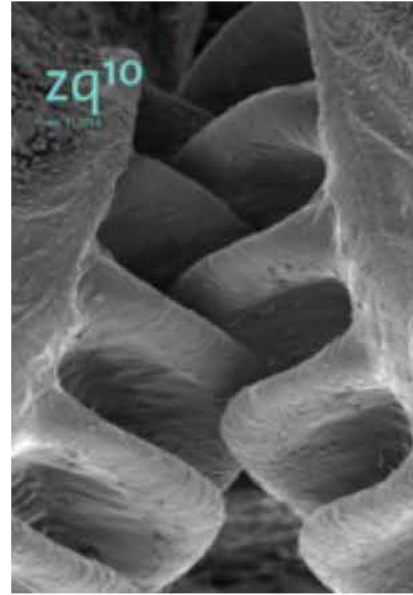
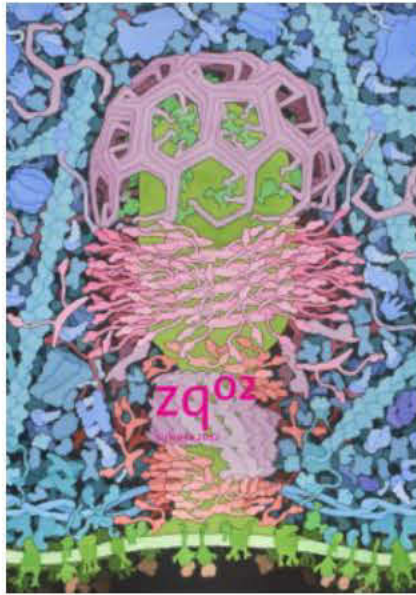
Marjan Eggermont

Designer, editor and  
publisher ZQ

[zqjournal.org](http://zqjournal.org)







Our mission is to establish  
a credible platform  
showcasing the nexus of  
science and design in the  
field of biologically  
inspired design.



# Scientific Writing vs Science Communication

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- Provides scientific context (references)
- Text > Graphics
- Focus on results & interpretation
- Provides societal context (examples)
- Text  $\cong$  Graphics
- Focus on conclusions & recommendations

# ZQ's founders

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- Tom McKeag is the program director of the University of California Berkeley Center for Green Chemistry (<http://bcgc.berkeley.edu>) where he co-teaches the Greener Solutions graduate course.
- Adjunct professor Industrial Design California College of the Arts, San Francisco, where he holds the BioWerks studio course.
- Tom writes the monthly Biomimicry Column at Greenbiz.com ([http://www.greenbiz.com/blogs/ featured/biomimicry-column](http://www.greenbiz.com/blogs/featured/biomimicry-column)),
- and is the founder and president of BioDreamMachine, a California public interest corporation dedicated to teaching BID



# ZQ's founders

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- Formally at IBM, Norbert Hoeller founded the design research and consulting practice Sustainable Innovation Network
- Director of BioDreamMachine (<http://biodreammachine.org/>),
- founder of the Bio-Inspired Design Community (<http://bioinspired.sinet.ca/>),
- and chair of the Canadian committee for ISO's Technical Committee on "Biomimetics" ([http://www.iso.org/iso/iso\\_technical\\_committee?commid=652577](http://www.iso.org/iso/iso_technical_committee?commid=652577))



# ZQ's founders

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- Biomimicry Institute Fellow and past member of Biomimicry Educational Advisory Board (BEAB)
- Board member American Society of Engineering Education (ASEE)
- In addition to a background in Fine Arts and Military History, a PhD Candidate in Computational Media Design, specializing in Bio-inspired Information Visualization
- Co-teach first year engineering design & communication to all 800 incoming students and introduce biomimicry.



# Contributing Editors

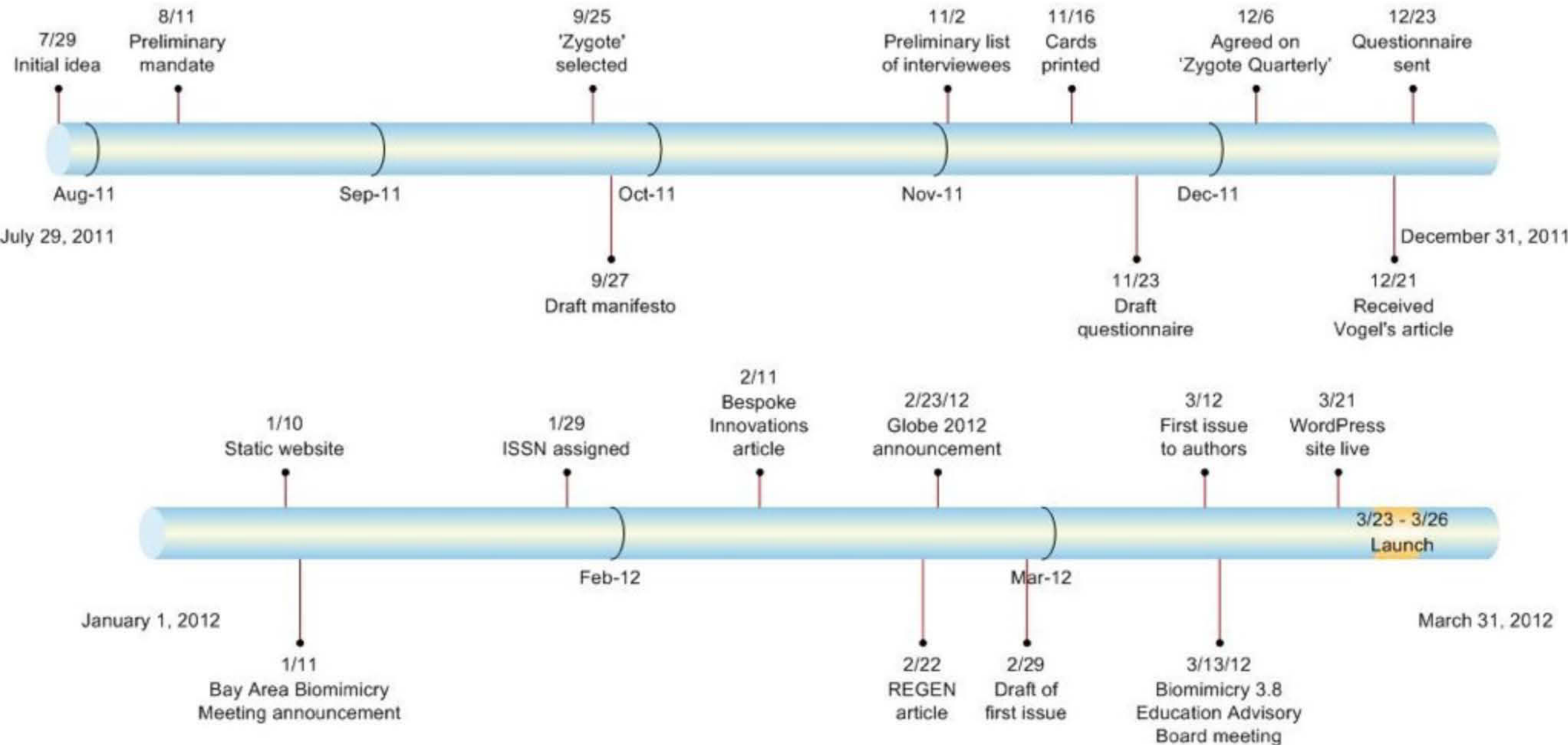
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- Kirsten Hoeller
- Heidi Fischer
- Raul de Villafranca
- Manuel Quirós
- Tanya Lynne Sakamoto
- Available in Spanish:





# Timeline to launch

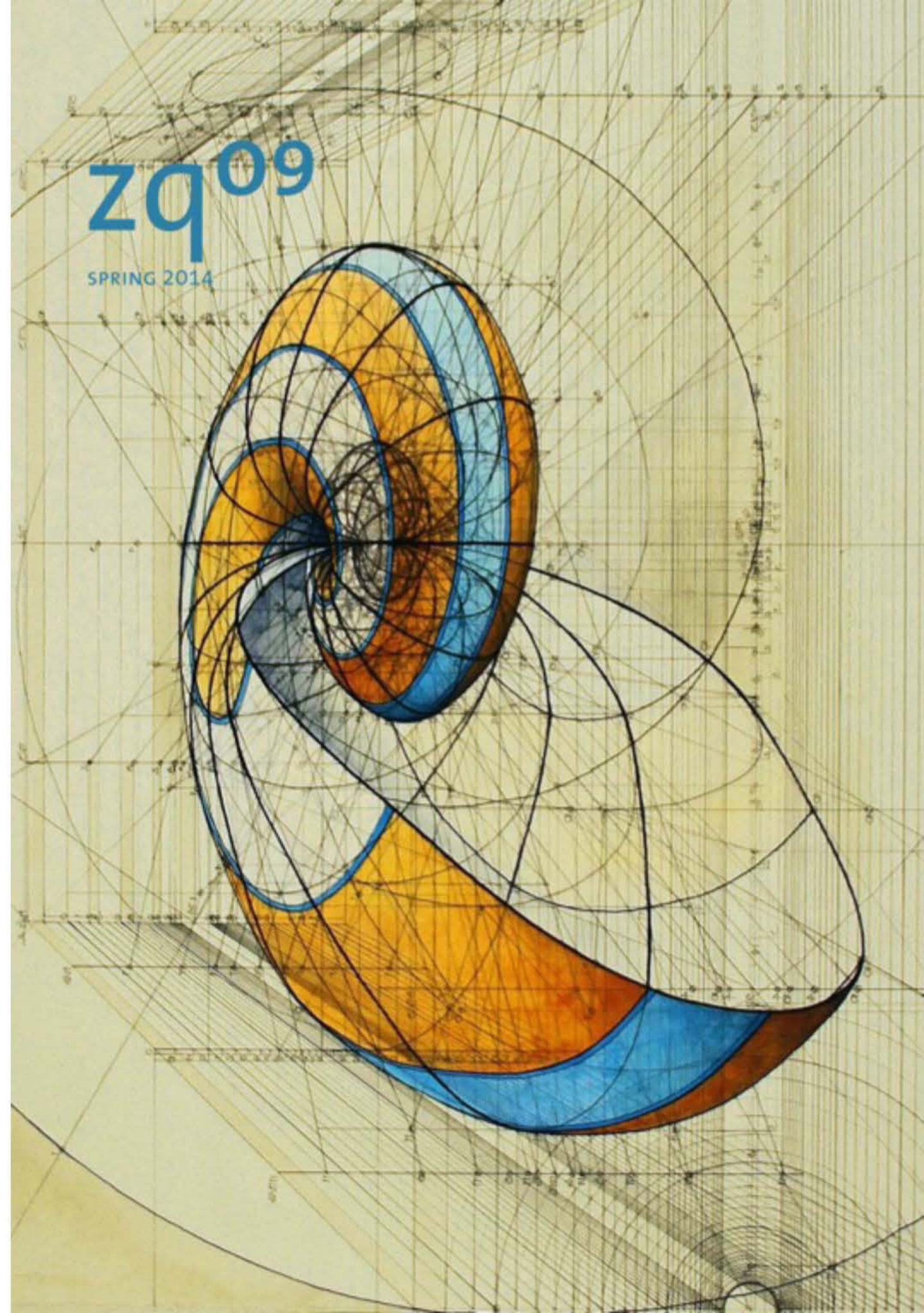




# ZQ provides

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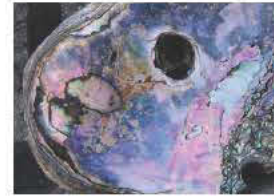
- Case studies
- Interviews
- Opinion pieces
- Tools and methodology
- Portfolios
- Product design
- Urban planning







Opinion: When Success Fails  
Steven Vogel 10



People: Interview with  
Julian Vincent 24



People: Interview with  
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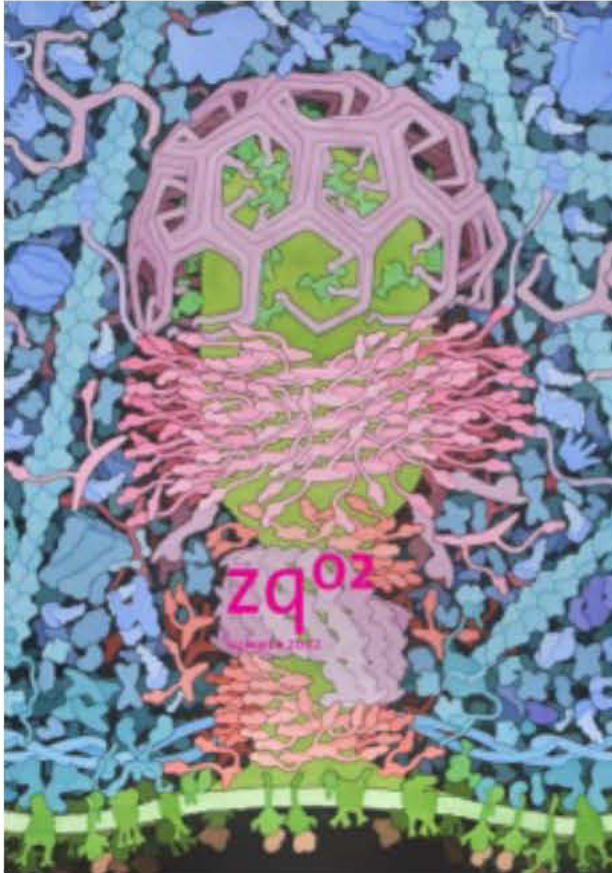
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Bespoke Innovations | Designed to the Bone  
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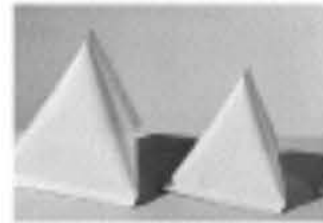
## Case Study: Auspicious Forms

Tom McKeag 10



## Tools: The Engineering to Biology Thesaurus

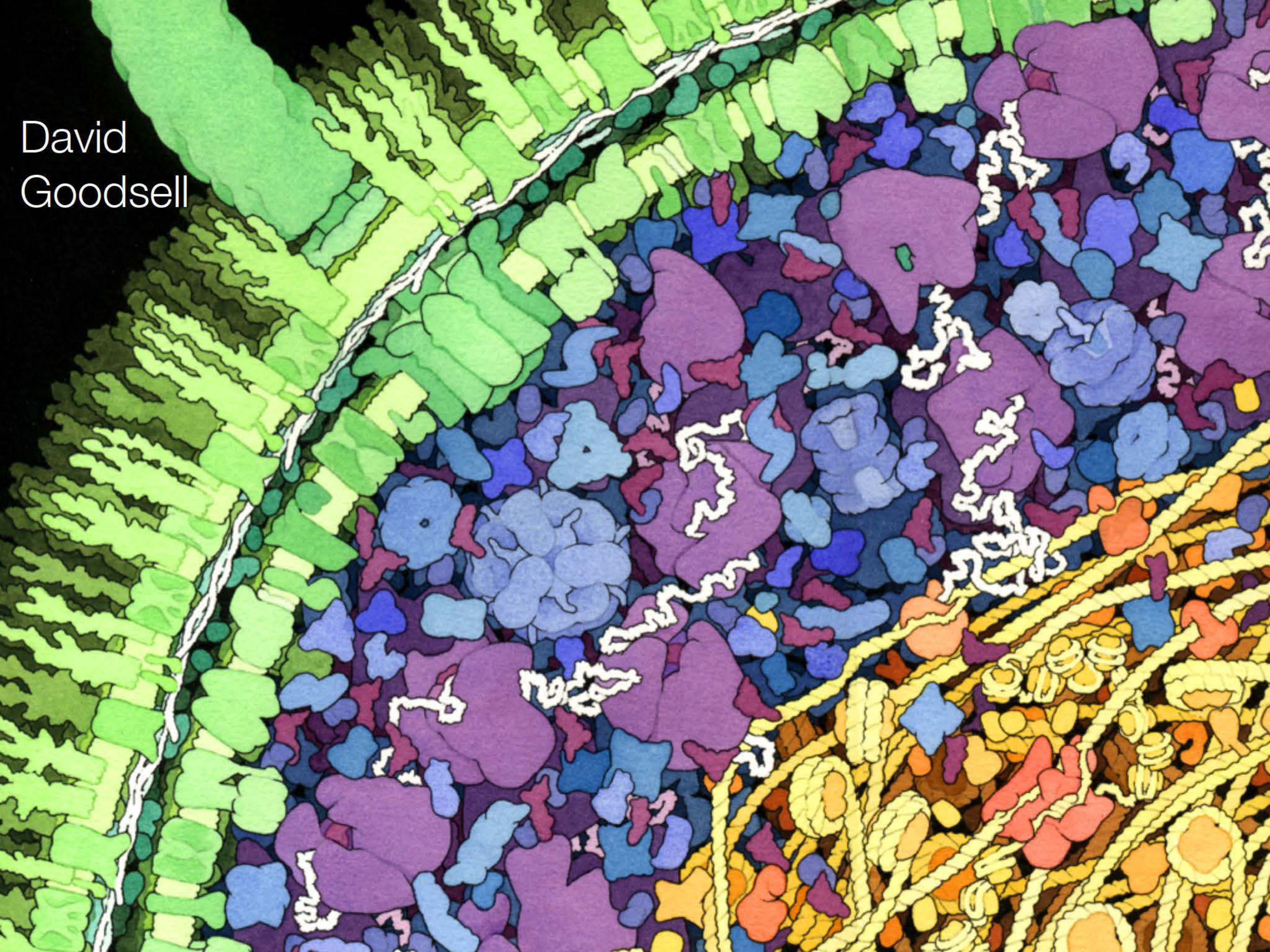
Jacquelyn Nagel 90



## Two Perspectives: Bucky and the Shape of Nature

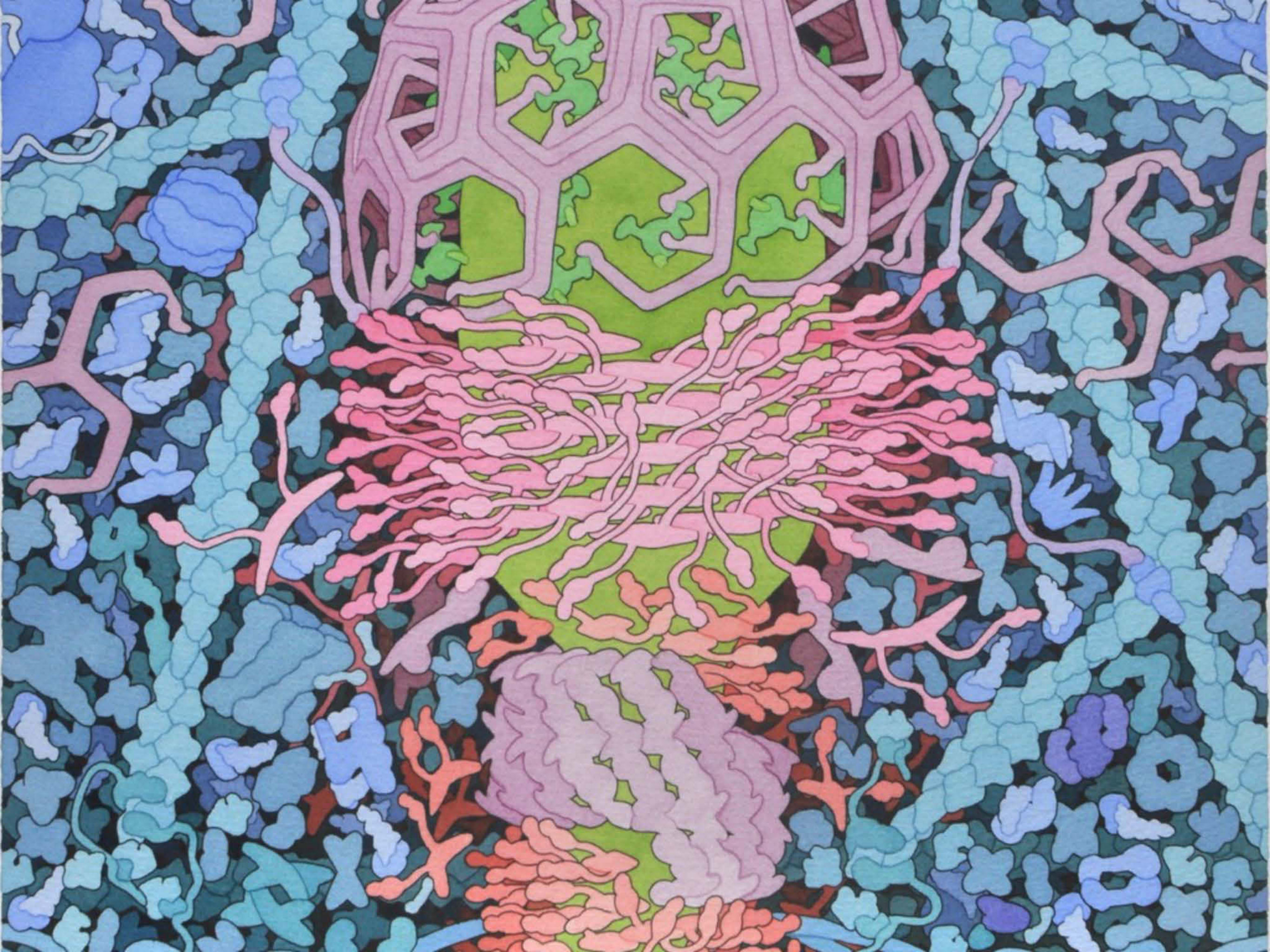
Curt McNamara 104





David  
Goodsell







## Auspicious Forms: Designing the Sanyo Shinkansen 500-Series Bullet Train

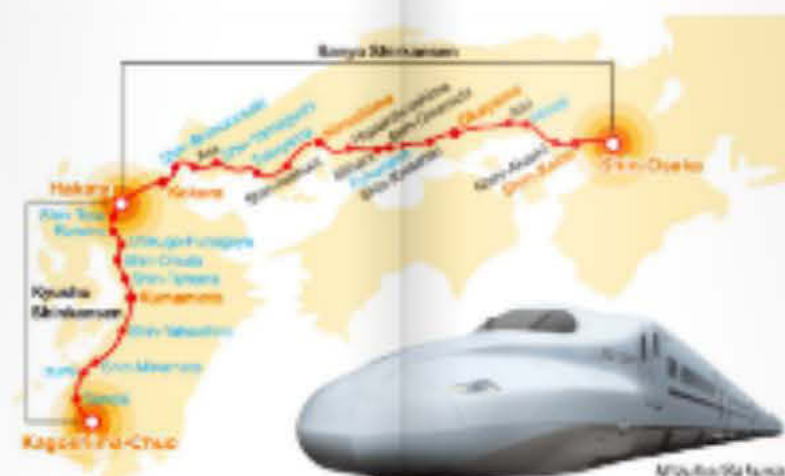
### The Background

The tiny notice in his local newspaper in 1990 would prove to be auspicious, in the deepest sense of the word, but Eiji Nakatsu did not know this at the time. Even now he is struck by the fatefulness of the little printed square. Few details were given, a lecture about birds by an aviation engineer at the Osaka branch of the Wild Bird Society of Japan. He decided to go and hear what a fellow engineer would say about his favorite topic.

"Auspicious" is derived from the Latin root "augur" and augury was the ancient Roman practice of studying the flight of birds in order to predict the future. It is a remarkably apt description of the next five years of Mr. Nakatsu's life, all set in motion by a scrap of newspaper. For Mr. Nakatsu was the General Manager of the Technical Development Department for one of the world's fastest trains, and he quickly realized that studying the flight of birds could indeed bring his train, and us, into the future.

The Sanyo and Kyushu Shinkansen Lines, operated by Japan Railway West and Japan Railway Kyushu, run between Shin-Osaka and Kagoshima at the southern tip of Kyushu Island. The line connects western Japan's two biggest cities, Osaka and Fukuoka, and is an extension of the older Tokaido Line from Tokyo to Osaka.

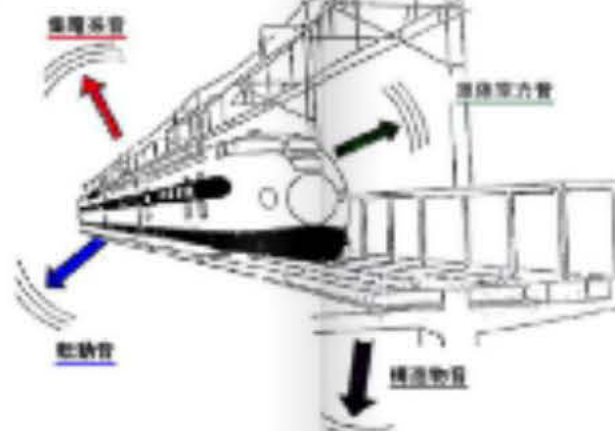
The 515 kilometer Tokaido Shinkansen is the world's busiest high-speed-rail line, having moved 4.9 billion passengers from its opening in 1964 (for the Tokyo Olympics) to 2010. Indeed, more people move by train in Japan than anywhere else in the world, and it is estimated that 64 million Japanese travel by rail of all sorts every day. Of this 40% share in world train traffic, 820,000 riders travel each day on the 2385 km of the total Shinkansen network.



● Stations served by Shinkansen and Tokaido lines  
● Stations served by Tokaido line only  
● Stations not served by Shinkansen

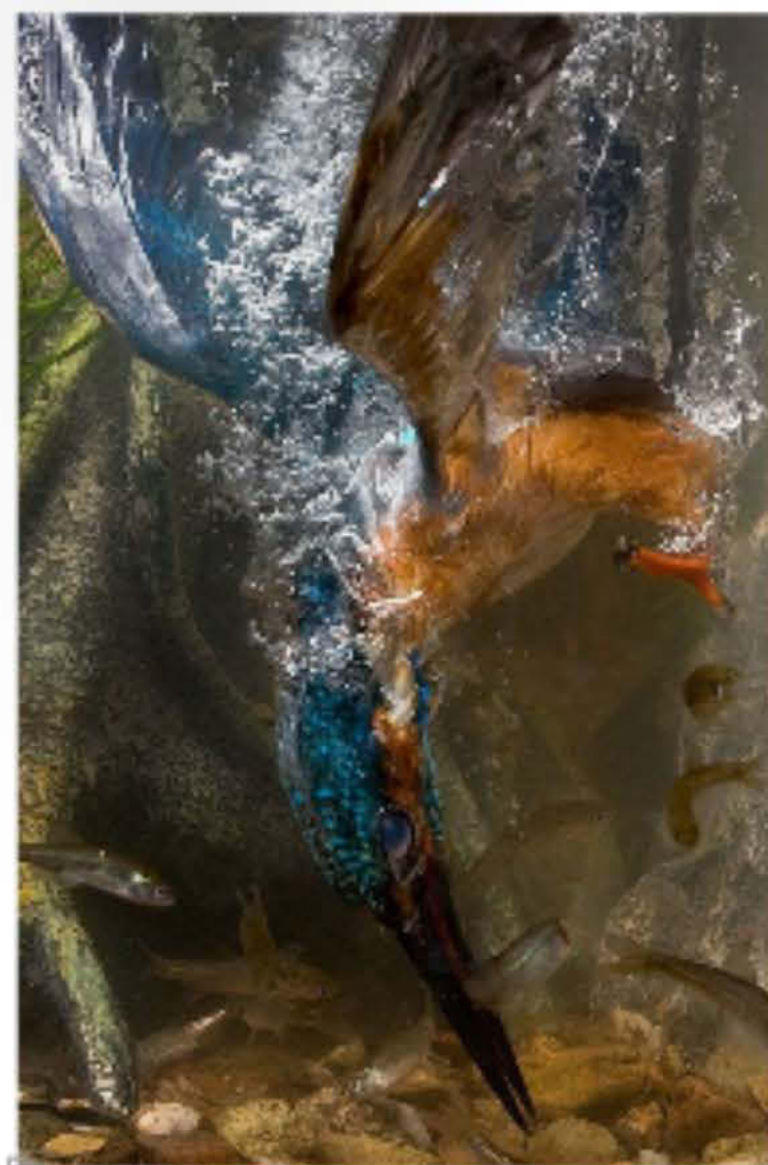
Expand

鉄道騒音の対策



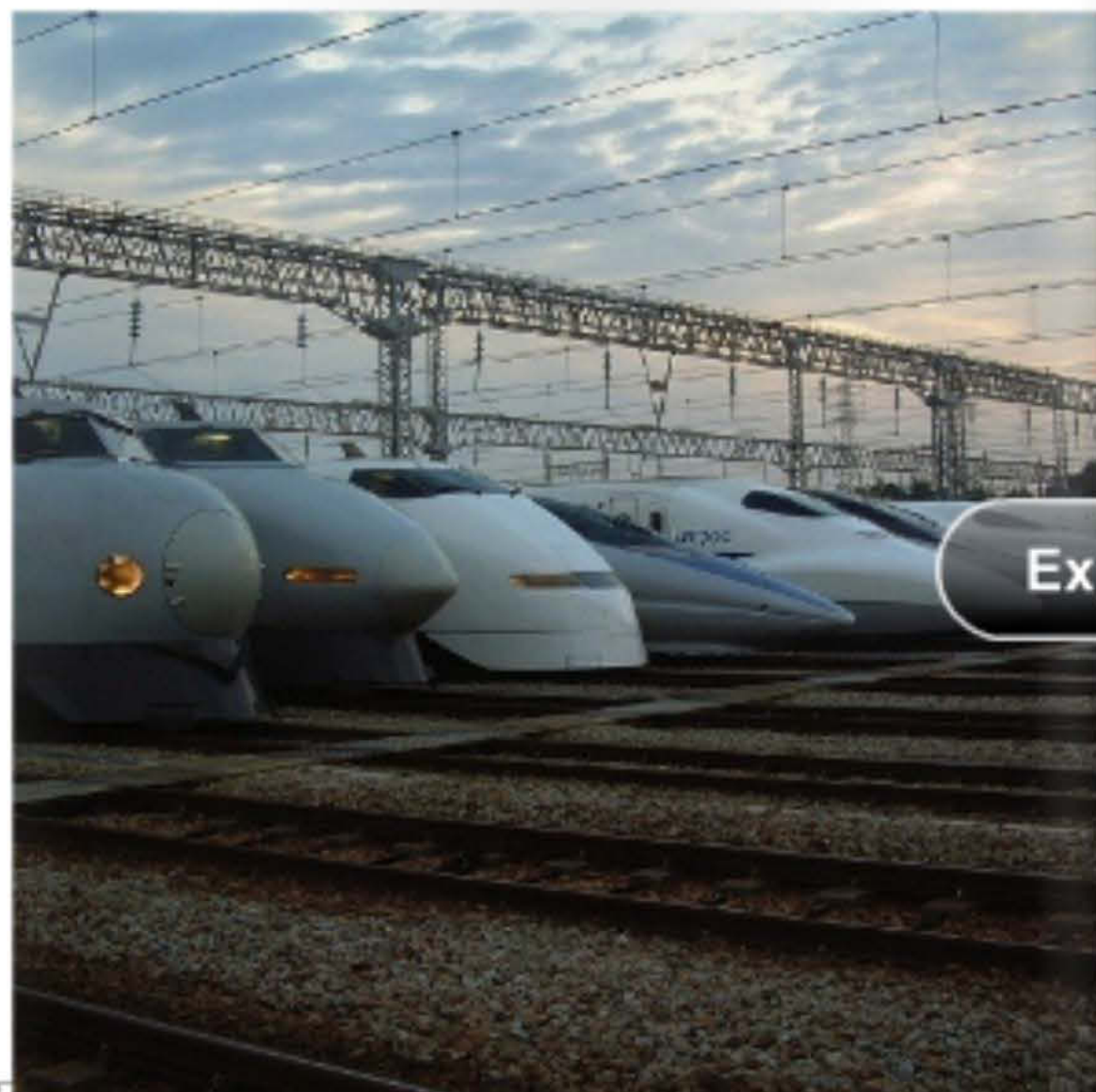
Sanyo & Kyushu Shinkansen Route  
Photo courtesy of Nakatsu, Eiji

Railway Noise Sources  
Photo courtesy of Nakatsu, Eiji



Unsettled Kingfisher - deep-dred  
Photo: nakatsu, 2011 (Fukuoka)





Expand

U, 100, 200, 300, 500, 700, 800 Series | Tokaido  
Shinkansen Line, Japan  
Photo courtesy of Tokaido Shinkansen



Shinkansen nose profile  
Photo: Shinkansen, 2005 | Tokaido Shinkansen

## The Design Process

The train then in service, the Shinkansen 300 series, had a more or less wedge-shaped nosecone, having supplanted the earlier bullet-nosed trains. This was compared with new alternatives by the use of scale models.

All of the Shinkansen companies were attempting to solve the sonic boom problem and RTRI made an intensive investigative effort. They found that the ideal nose was either a wedge or a rotational parabolic body with a section that changed area by a constant ratio.

As with the owl, the JR West team obtained the natural artifact and analyzed its dimensions and materials. What Mr. Nakatsu found was that the bill of the kingfisher was consistently round in cross-section, and he described it as "a circular lozenge surrounded by four circles". The kingfisher bill can also be described as a rotational parabolic body. Both the upper and lower beaks of the bird have triangular cross-sections with the sides of the triangles being curved. Together they form a squashed diamond shape, the same shape that would be formed in the intersection of four perfect circles pecked together.

Informed by these parameters, RTRI set about to test various nose shapes in a 1-to-scale model tunnel and measure the pressure waves generated. They shot bullets of various shapes into a pipe, from the more traditional bullet nose to sharper shapes, including that of the kingfisher bill. Concurrently these same shapes were run in simulations on a space research supercomputer. A train nose very similar to the bill of the kingfisher was then selected. All the tests confirmed what could be observed in real life: the shape of the kingfisher bill was, indeed, the most efficient of all those tested, beating all alternatives by a wide margin. Refined prototypes were built and ultimately made to full-scale for test runs on the tracks.

It was at this point that Mr. Nakatsu became convinced that nature had much to teach about efficient forms. His initial inspiration had been confirmed by the results of both the large scale instrument tests and the analysis of the supercomputer. In a dramatic 2004 demonstration of the streamlined quality of the kingfisher beak, TV Asahi broadcast a program showing the differences in splash created when a simple cone and a rotational parabolic body are each dropped into water.





## Case Study: Return of the Swamp Thing

Tom McKeag 10



## Tools: Developing Cross-Domain Analogies using Natural-Language Sources

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## Learning from the Master Shape-Shifter

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## Opinion: There Are No Strangers in the World

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## Article: Seeking Intelligence Inside the Swarm

Clint Penick 38





Philip  
Beesley









## Case study: Requiem for a Butterfly : Mirasol's Market Meltdown

Tom McKeag 10



## Opinion: Why Don't Solar Panels Look Like Trees?

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## Tools: Structure-Behavior-Function and Functional Modeling

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## Tools: Framing Your Problem with the Bio-Design Cube

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## People: Interview with

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## Case Study: Making Paste

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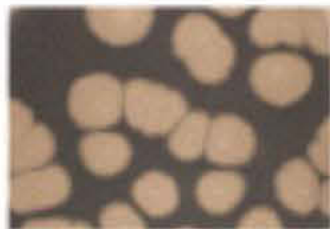
## Special Feature: "Looking back, looking forward"

Janine Benyus In conversation with Megan Schuknecht 40



## Case Study: What a Drag! You Mean These Bumps Didn't Make Me Swim Faster?

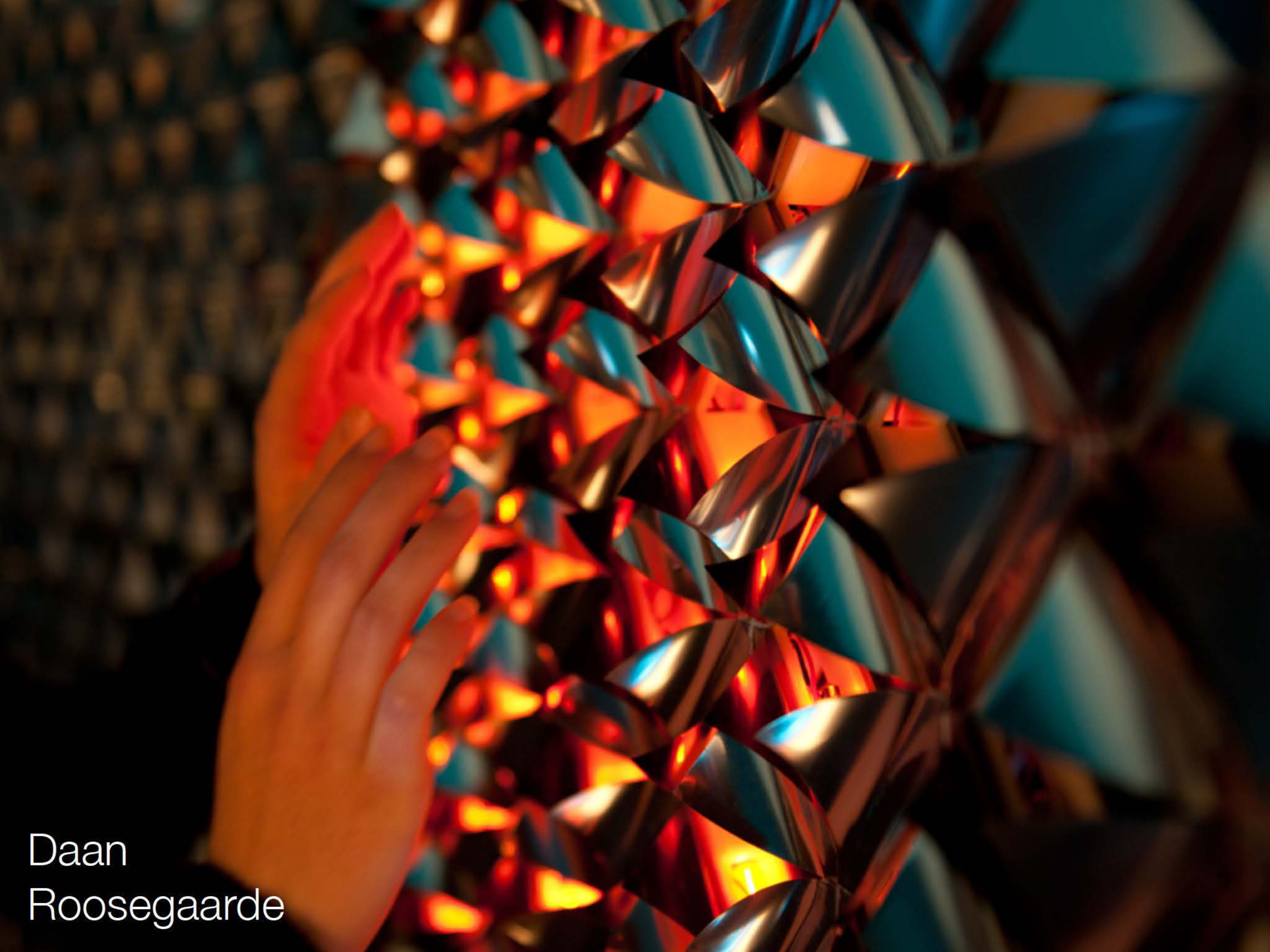
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## The Science of Seeing: Tales from the Belly Button

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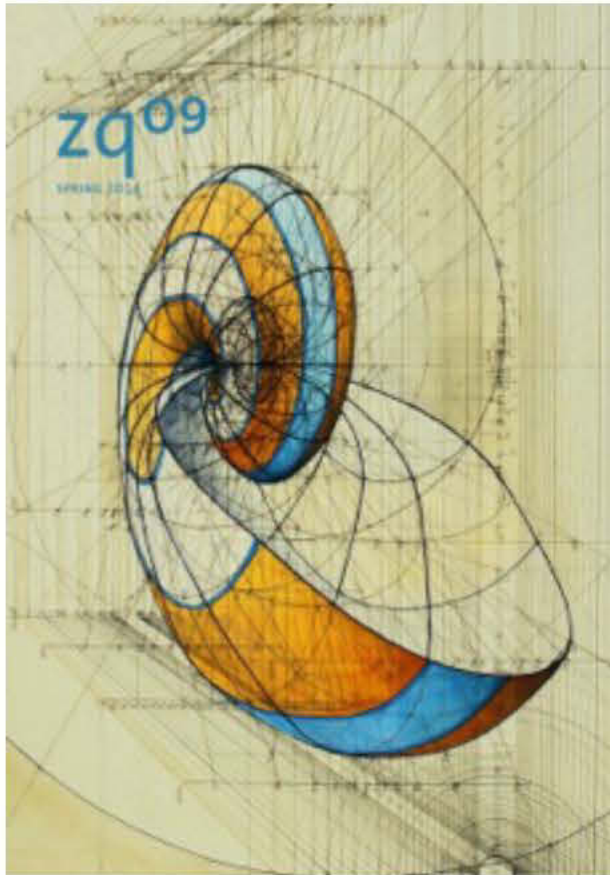


Daan  
Roosegaarde









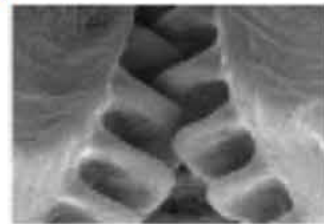
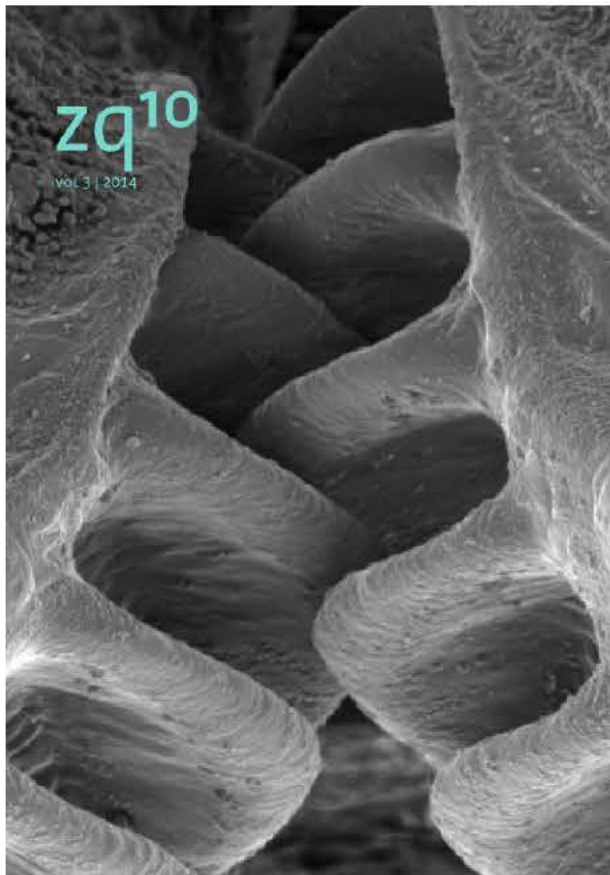
## Case Study: Little Things *Multiply* Up: Hierarchical Structures

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Tom McKeag 8



## Article: The ISO/TC 266 Biomimetics Standard Initiative

Taryn Mead and Norbert Hoeller 72





# Case Study *Gearing Up (and away): How a little backyard bug might change engineering*

Click to read

Tom McKeag

Image courtesy of Malcolm Burrows



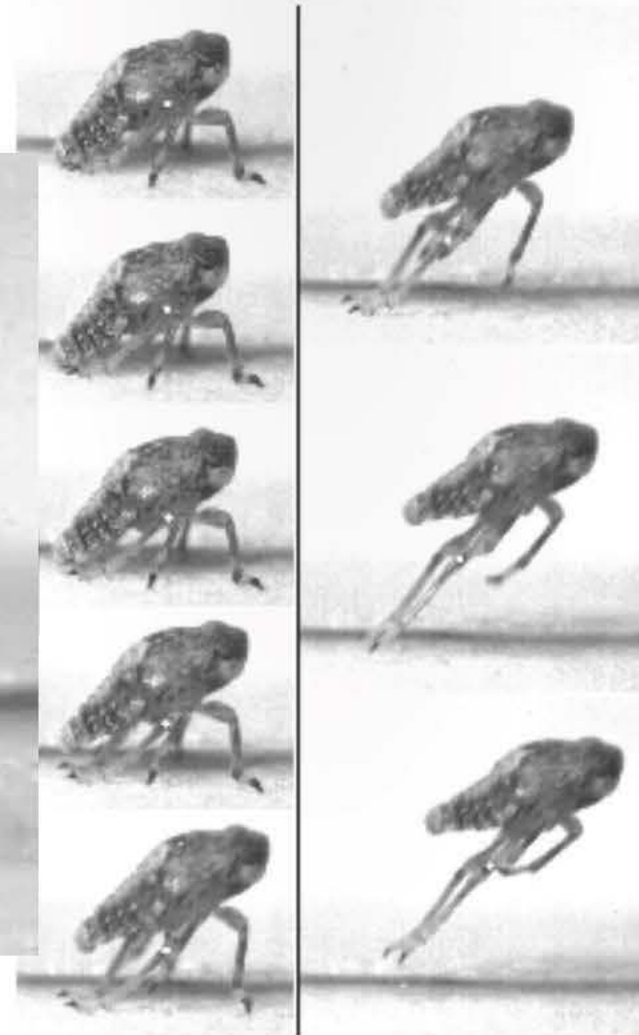
for his anthropomorphic analogy, Dr. Sutton re- that it returns to its original shape after each



together, however, and you get to a structure like an archery bow; the resin will prevent the structure cracking and will always ensure

or escape predators.

The strips have 10 to 12 gear teeth, asymmetric in their form, looking like shark fins on just

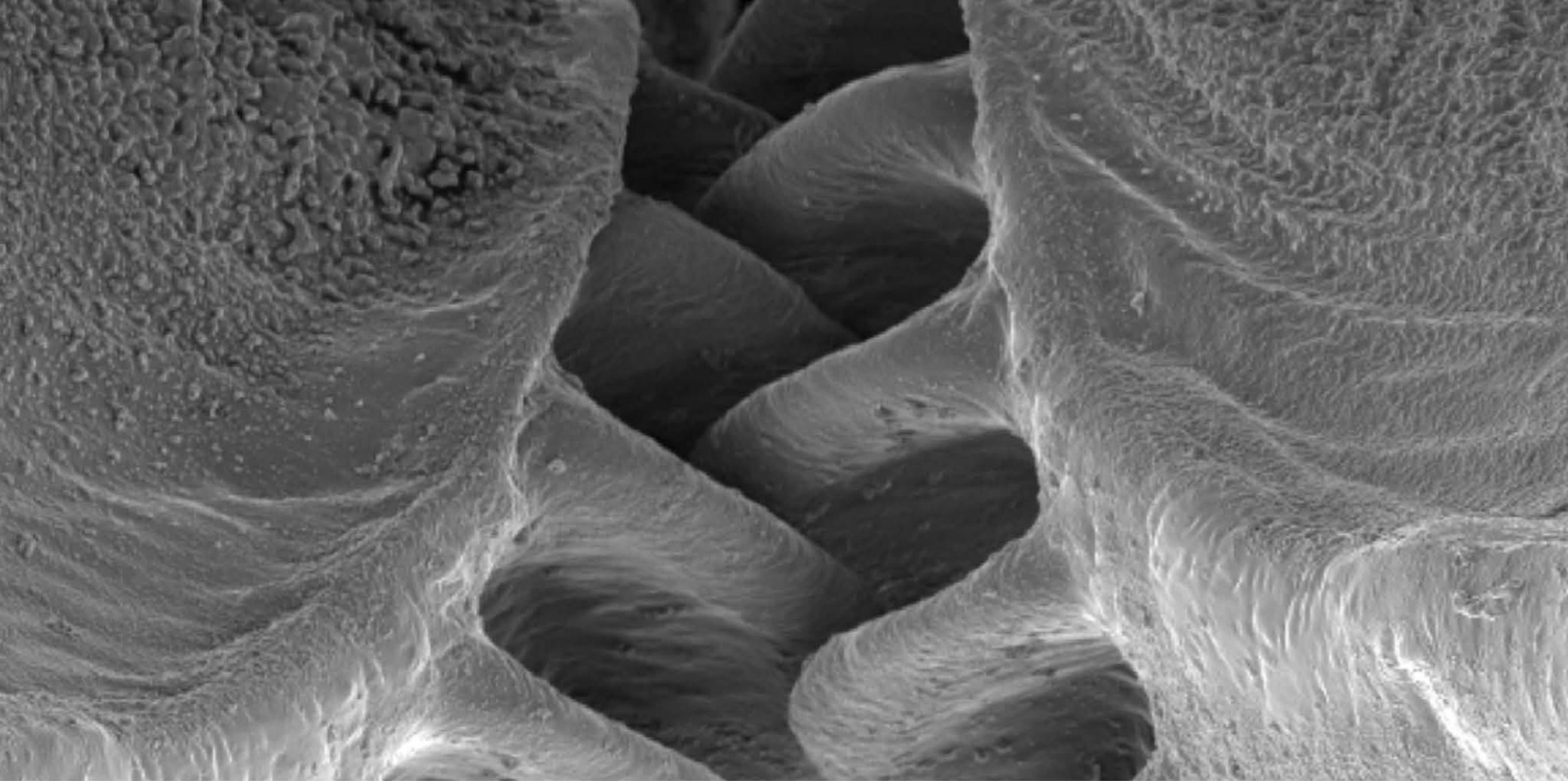


Jump sequence

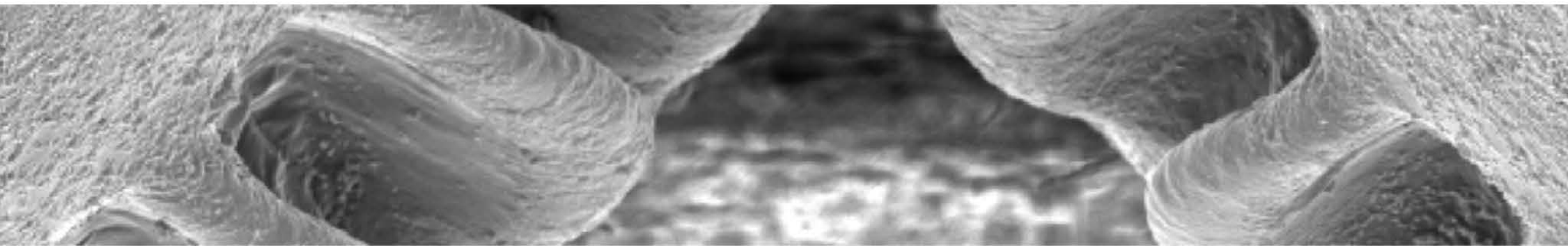
Photo courtesy of Malcolm B. Brown

200





*Issus* nymph gears

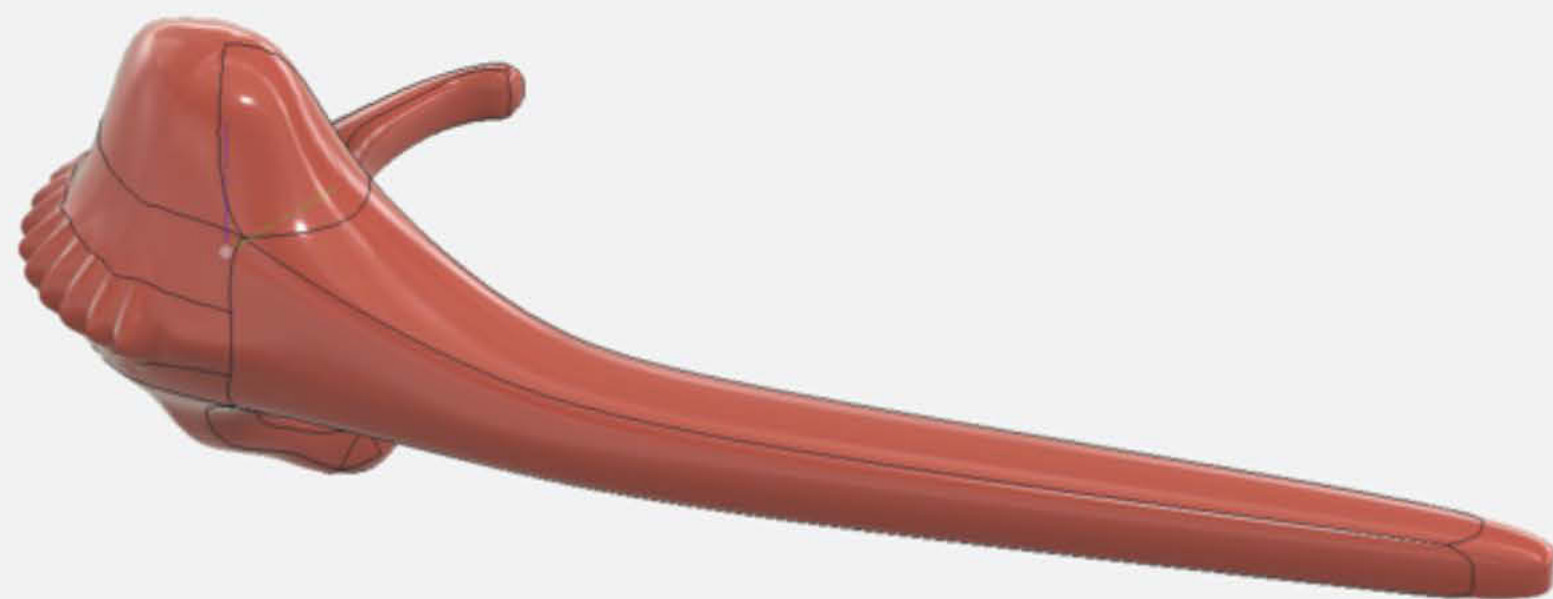




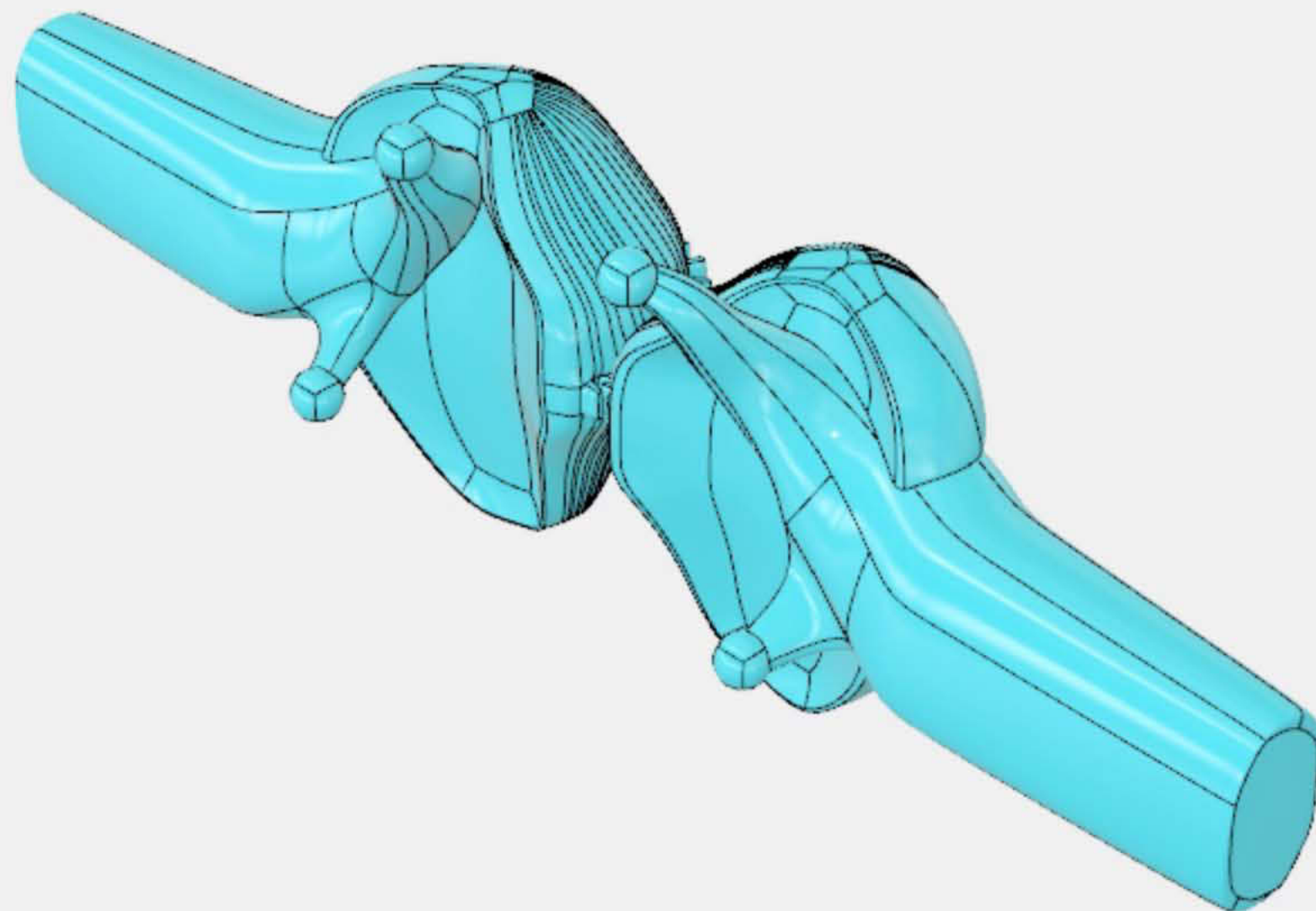


100  $\mu\text{m}$

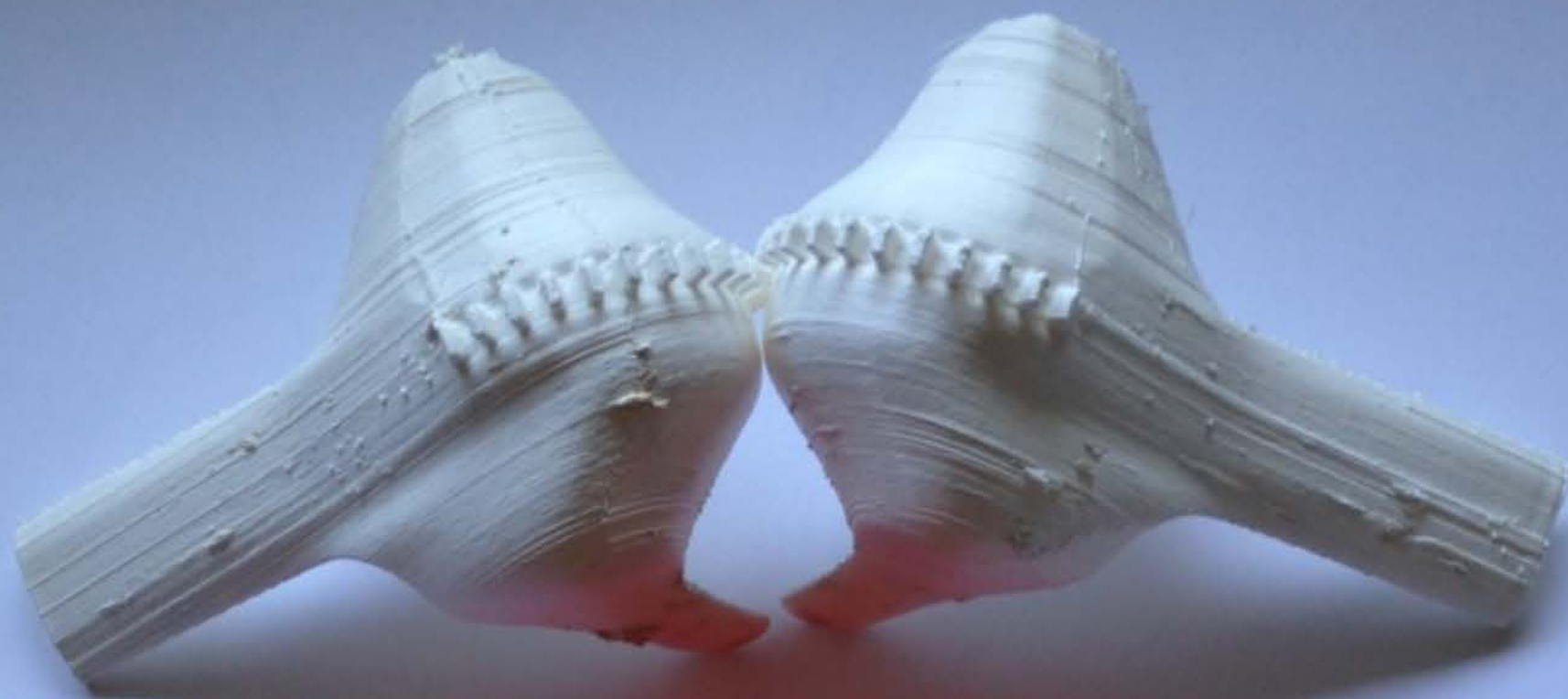


















# 3D printed insect gears observation 1

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- The 'gears' are recessed and are remarkably self-aligning
- Backlash free (any tension in the animal takes up 'play')

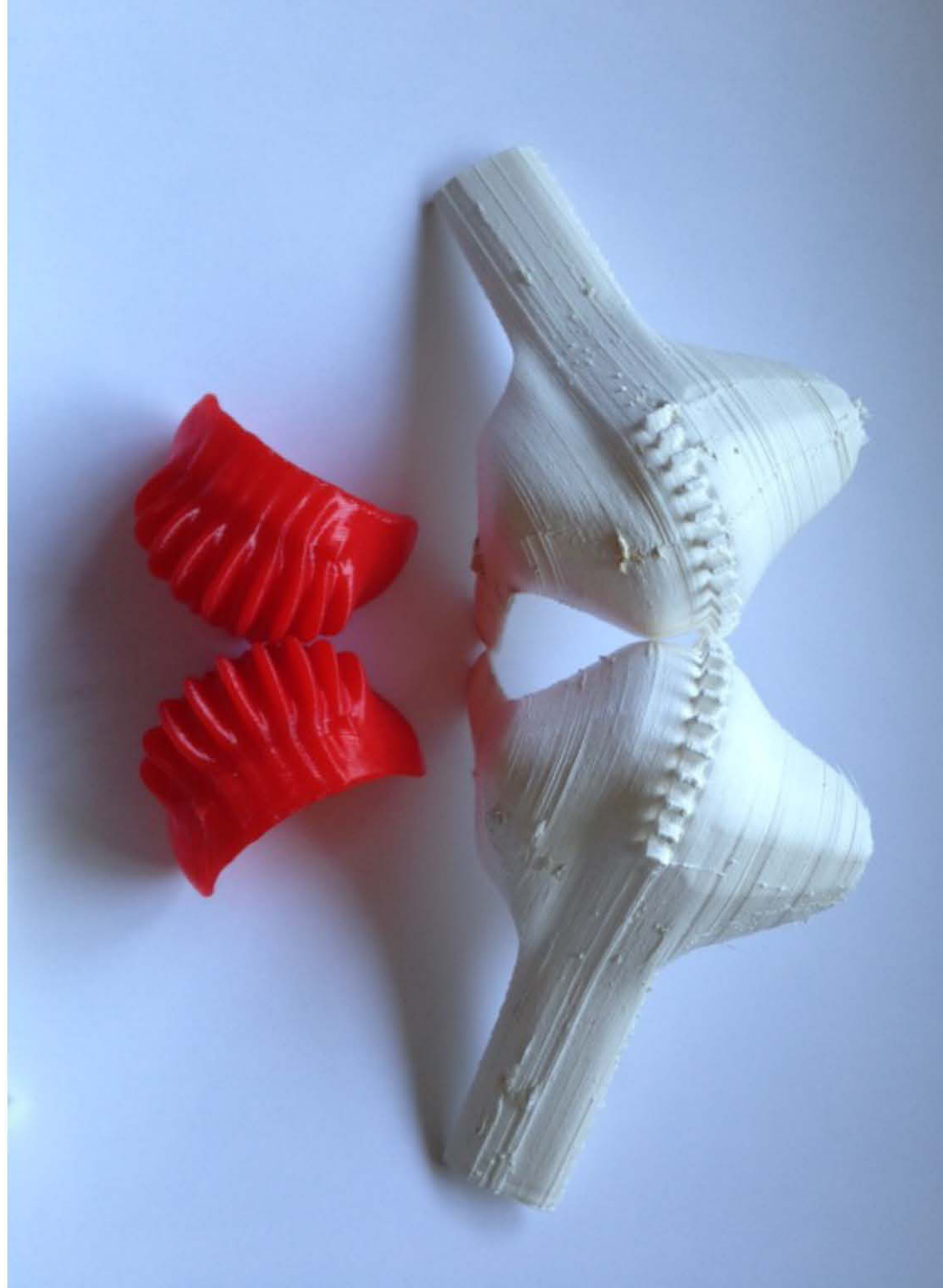




# 3D printed insect gears observation 2

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- The 'gears' are a one-directional timing mechanism
- They don't transmit much power but they allow very precise orchestrated movements





# 3D printed insect gears observation 3

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- The 'gear' shape sweeps through a subtle 3D path (the software had trouble with this)





# 3D printed insect gears observation 4

---

- While we could not see many animals it looked like a robust system: able to deal with more shape variation in the 'teeth' than the engineering equivalent gear trains
- Applications: evolved mechanisms, ad hoc hinges and latches, and other seldom-used orchestrated movements (closing jaws, multi-linkage mechanisms)





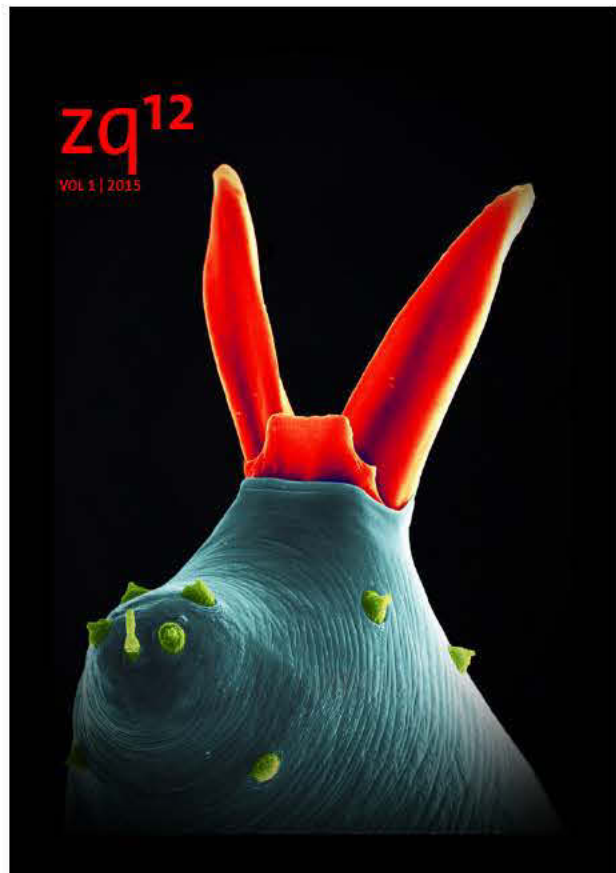


## Case Study: Sahara Forest Project: Seeing the Forest For the Trees

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## World: Interview with The Bionic Learning Network of Festo 94



## Case Study: Sticky Wicket: A Search for an Optimal Adhesive for Surgery

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## The Science of Seeing: Stories *and* Atoms

Adelheid Fischer 42



## Book: Engineered Biomimicry by Akhlesh Lakhtakin and Raul J. Martin-Palma, Eds.

Reviewed by Michael S. Ellison 56



# Festo's Bionic Learning Network

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Students were given a demonstration of their BionicOpter and we, as the teaching team, followed up with a bio-inspired design project.









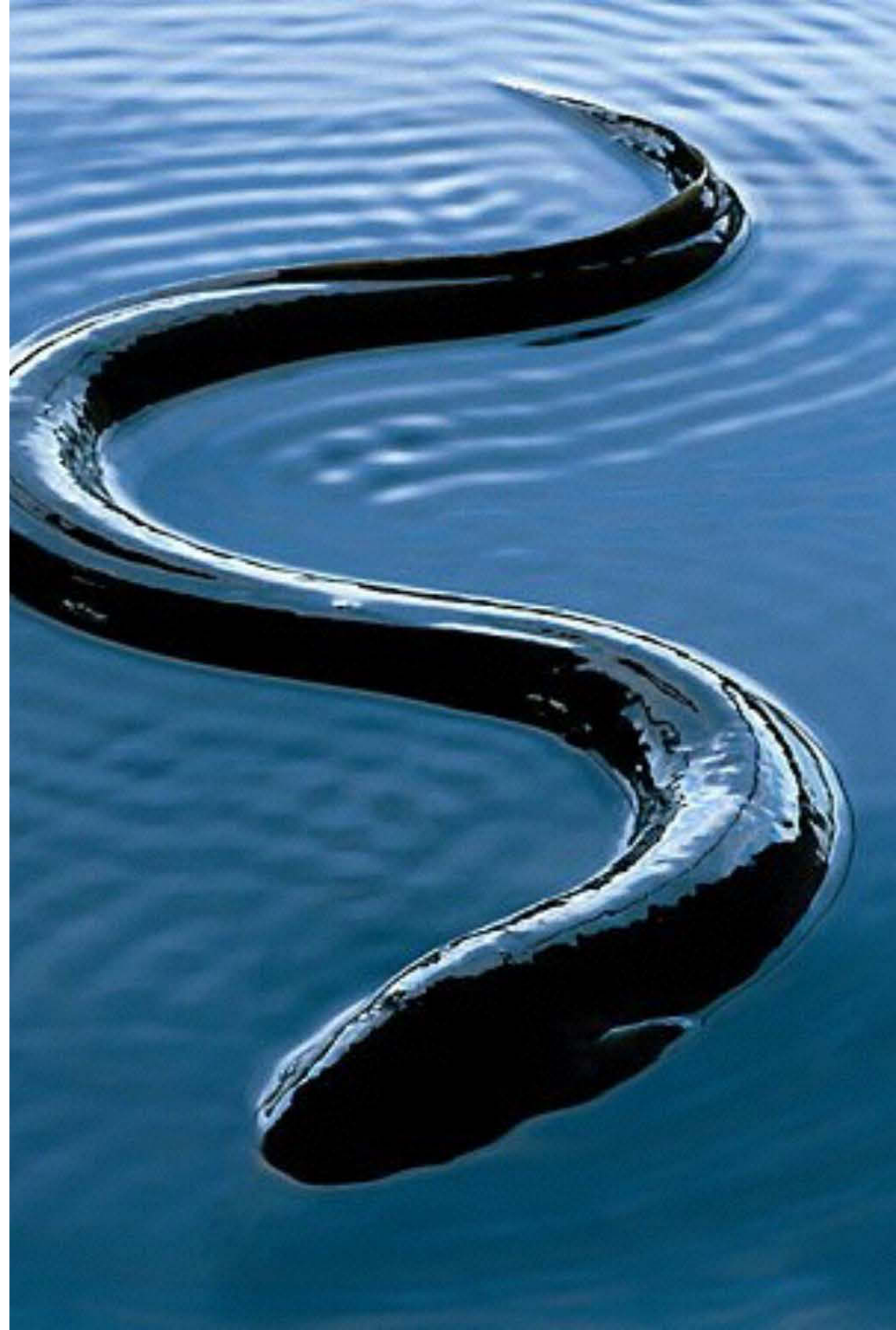
# Water locomotion device

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The project: to design and build a biomimetic device that travels through water. Each team was assessed on:

The ability of their device to utilize a biomimetic means of propulsion to traverse a water trough;

The communication of the team's design process, including: development and analysis of alternative solutions, prototyping, and testing.

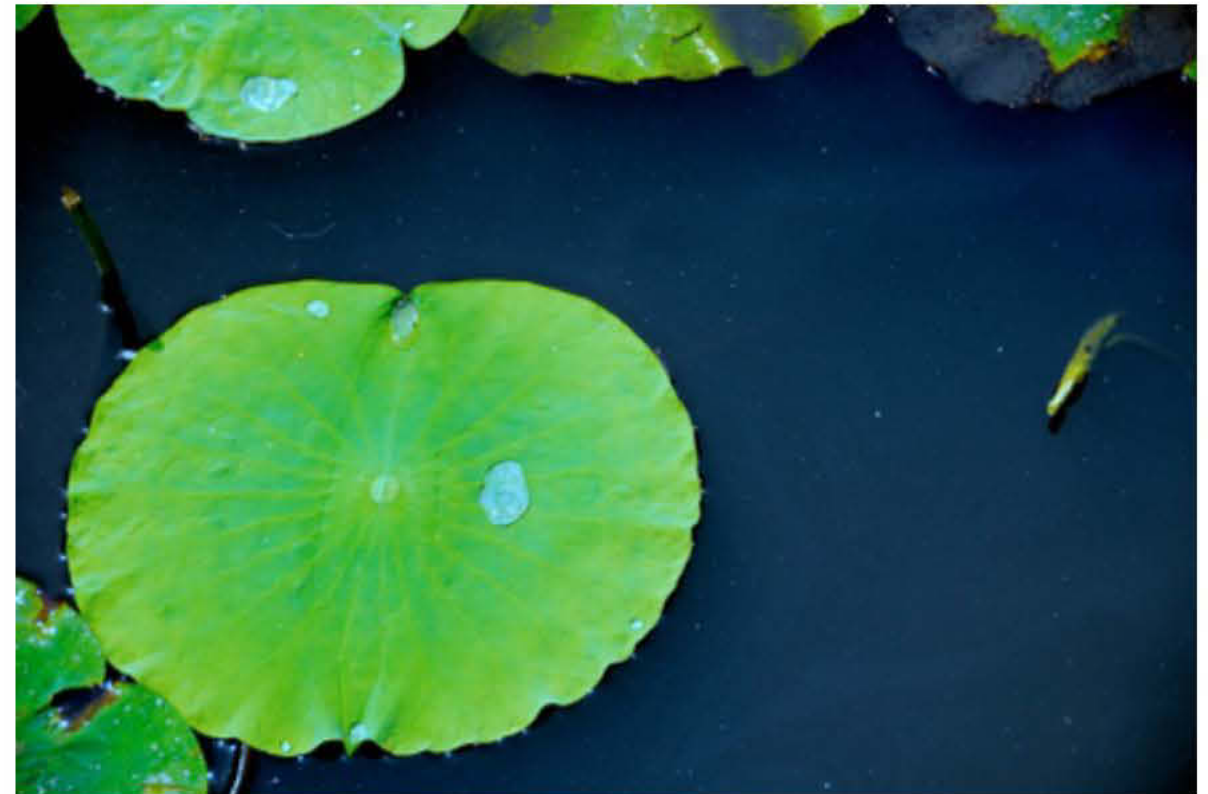
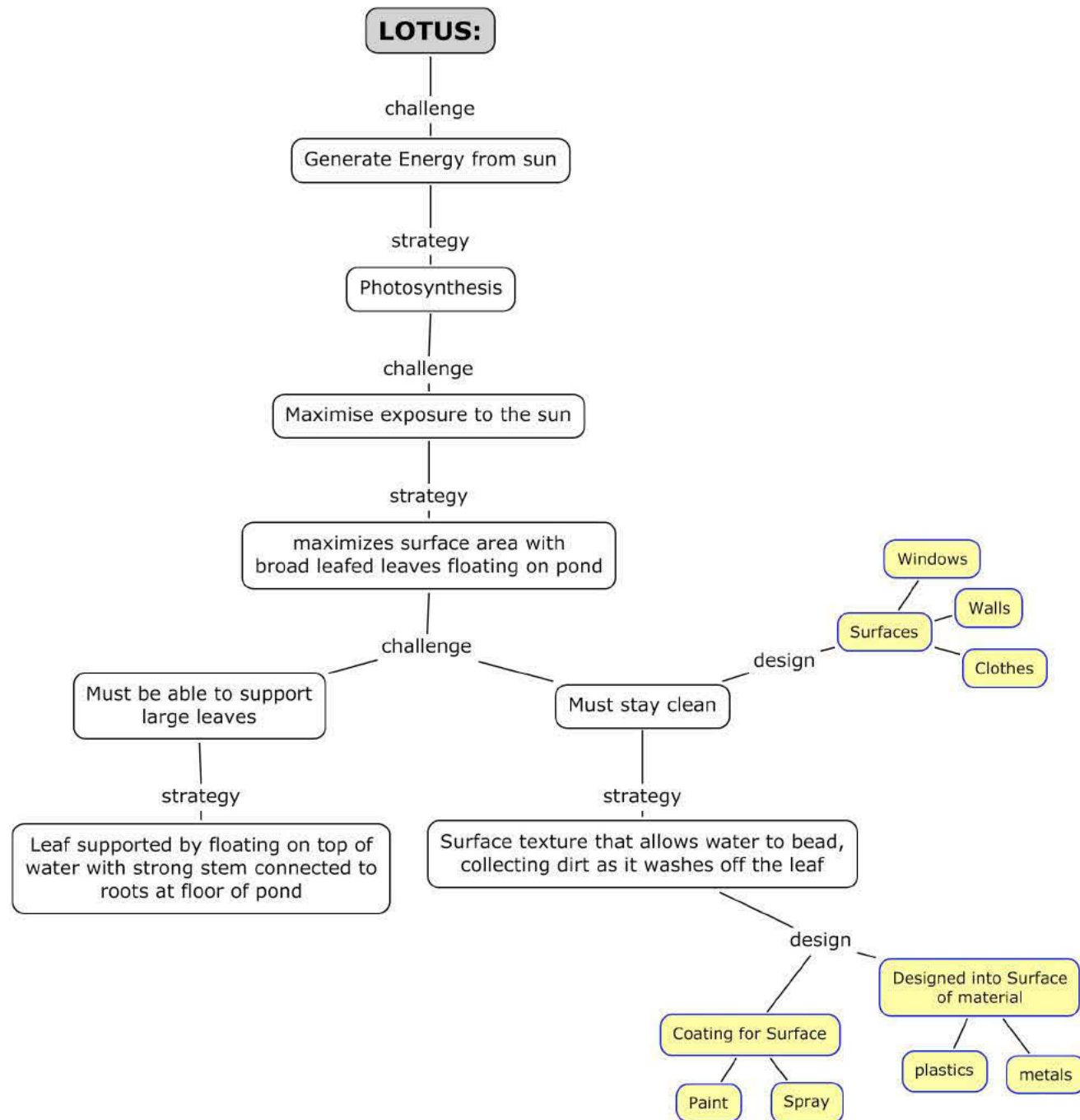




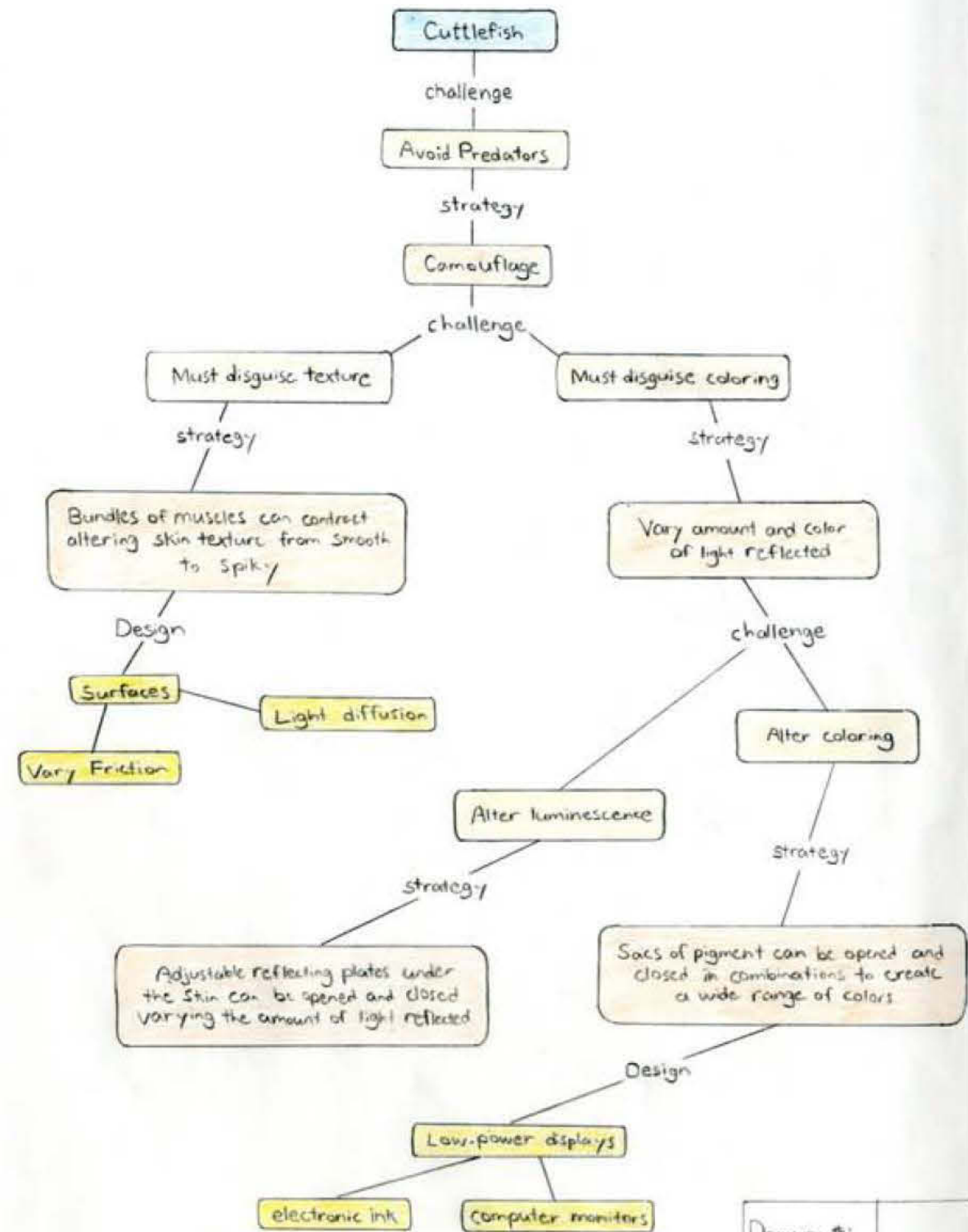
**Other work with the students**



Students create a map of challenges and strategies based on an organism they have found on asknature.org:







Drawing #:	
Title:	Cuttlefish
Date:	6/
Scale:	



# CHAMELEON

## CHALLENGE

Maintain a view from all directions at all times

## STRATEGY

Eyes are conical shaped, and mounted on turret like platforms/  
The eyes can move independently from one another.

## CHALLENGE

Must be able to avoid predators

## STRATEGY

The 360 degree eye movement allows for constant views of the area

## DESIGN

## SAFETY

Aviation

Security Cameras

Military Scopes

Air Traffic Control

Shipping

Security

## DESIGN

Needs to seek prey for food

## STRATEGY

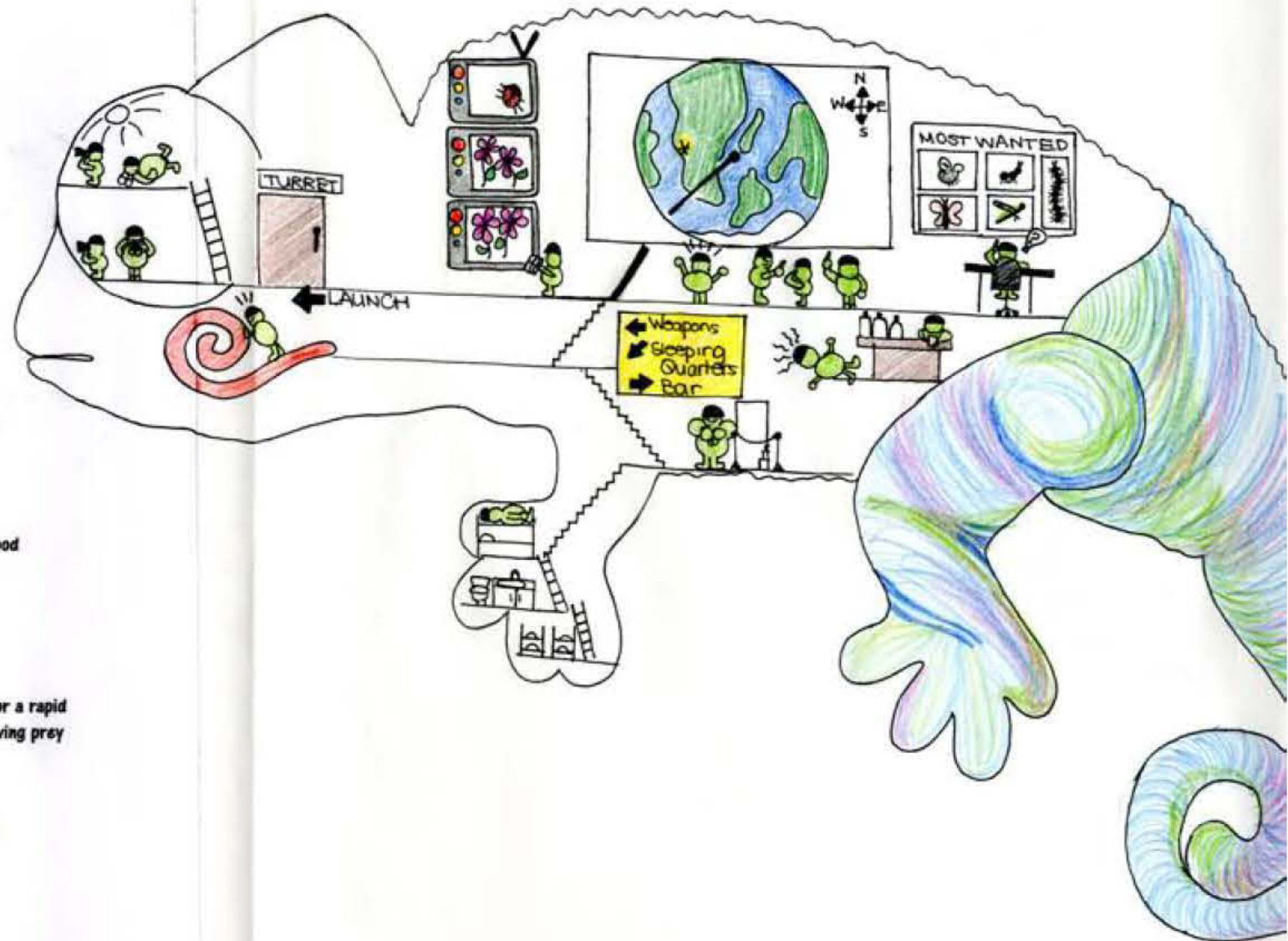
360 degree eye movement allows for a rapid scan of the area for small quick moving prey

## CHALLENGE

Capturing Prey

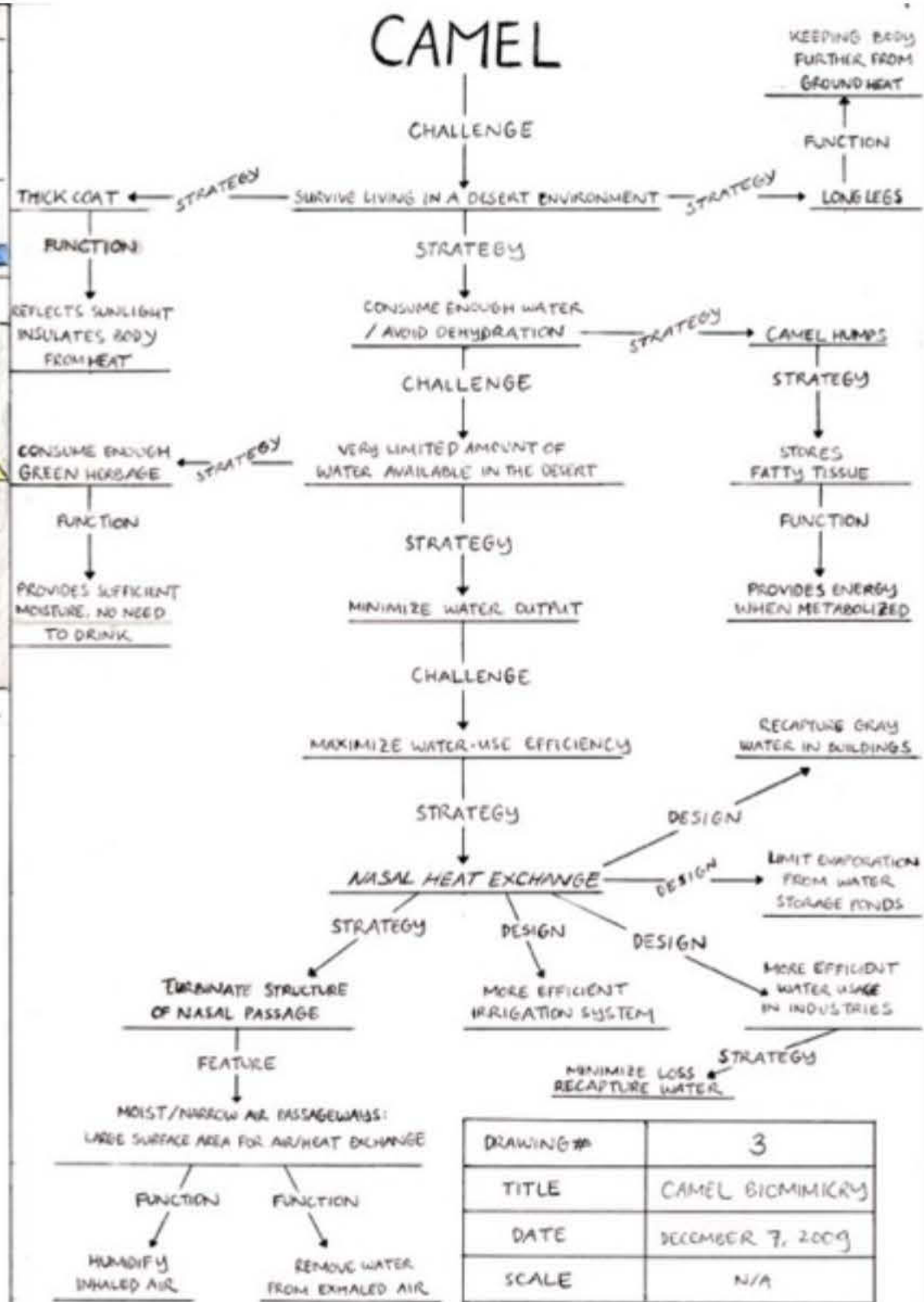
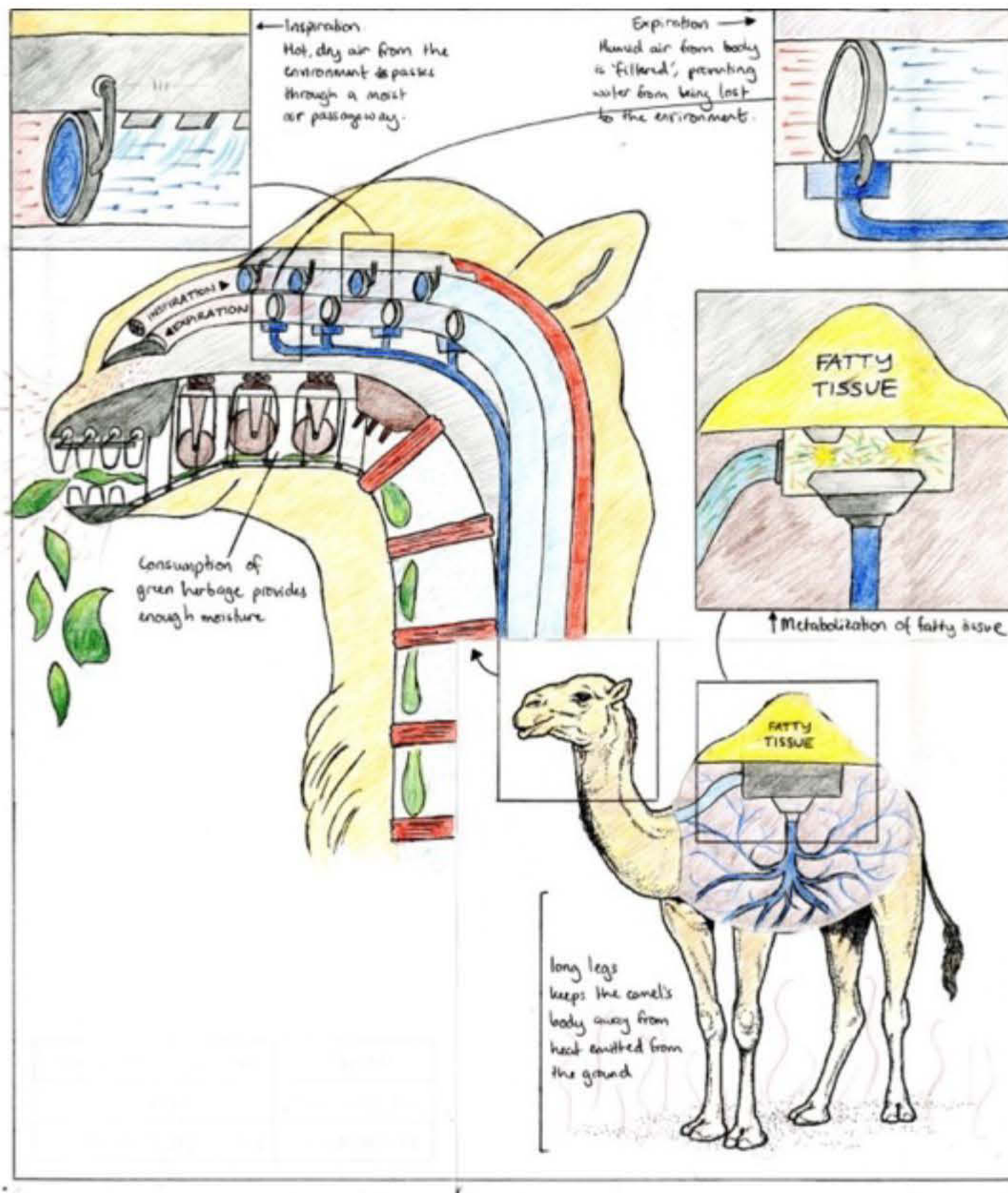
## STRATEGY

Together creates binocular vision in front, allowing for an accurate strike with its tongue

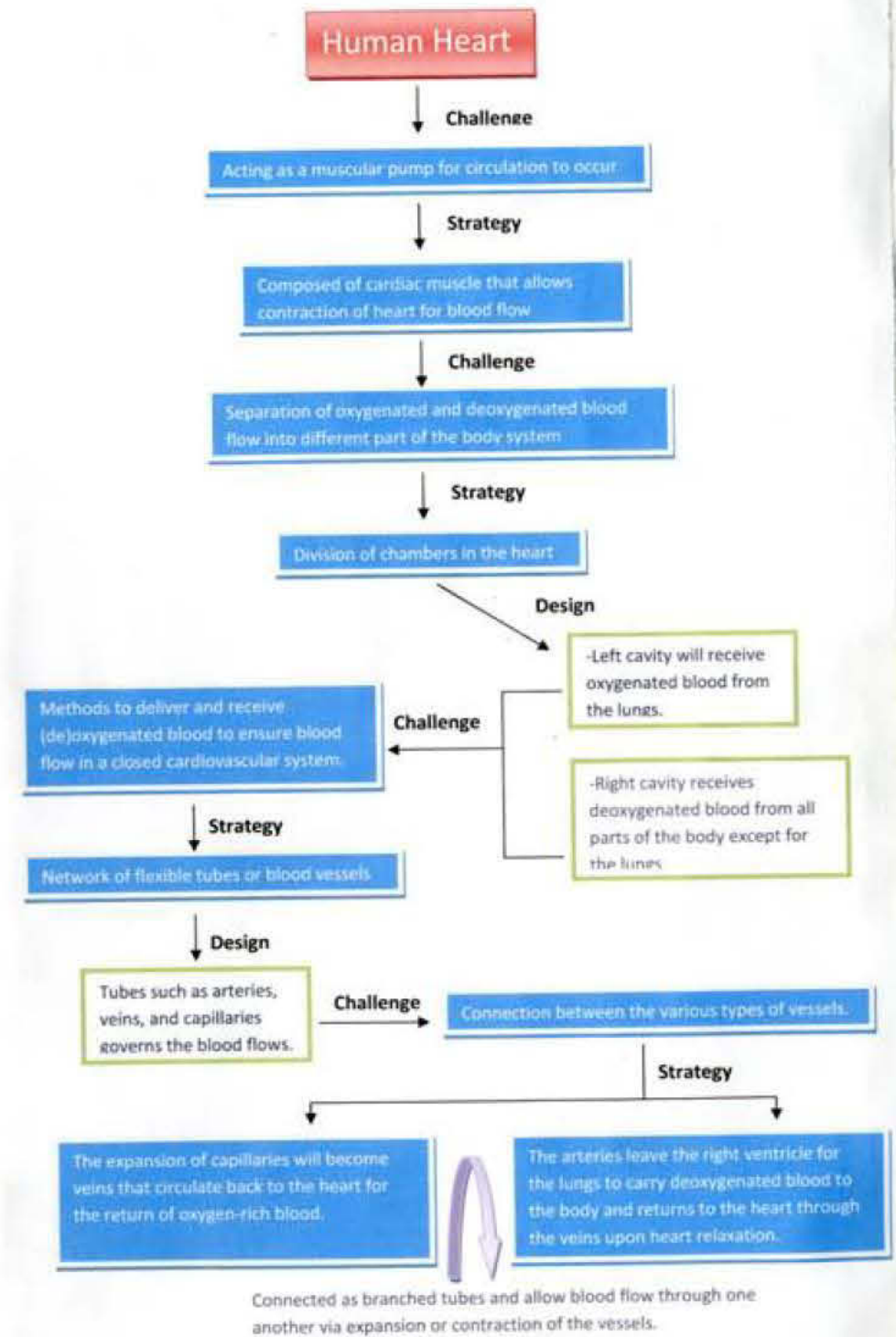
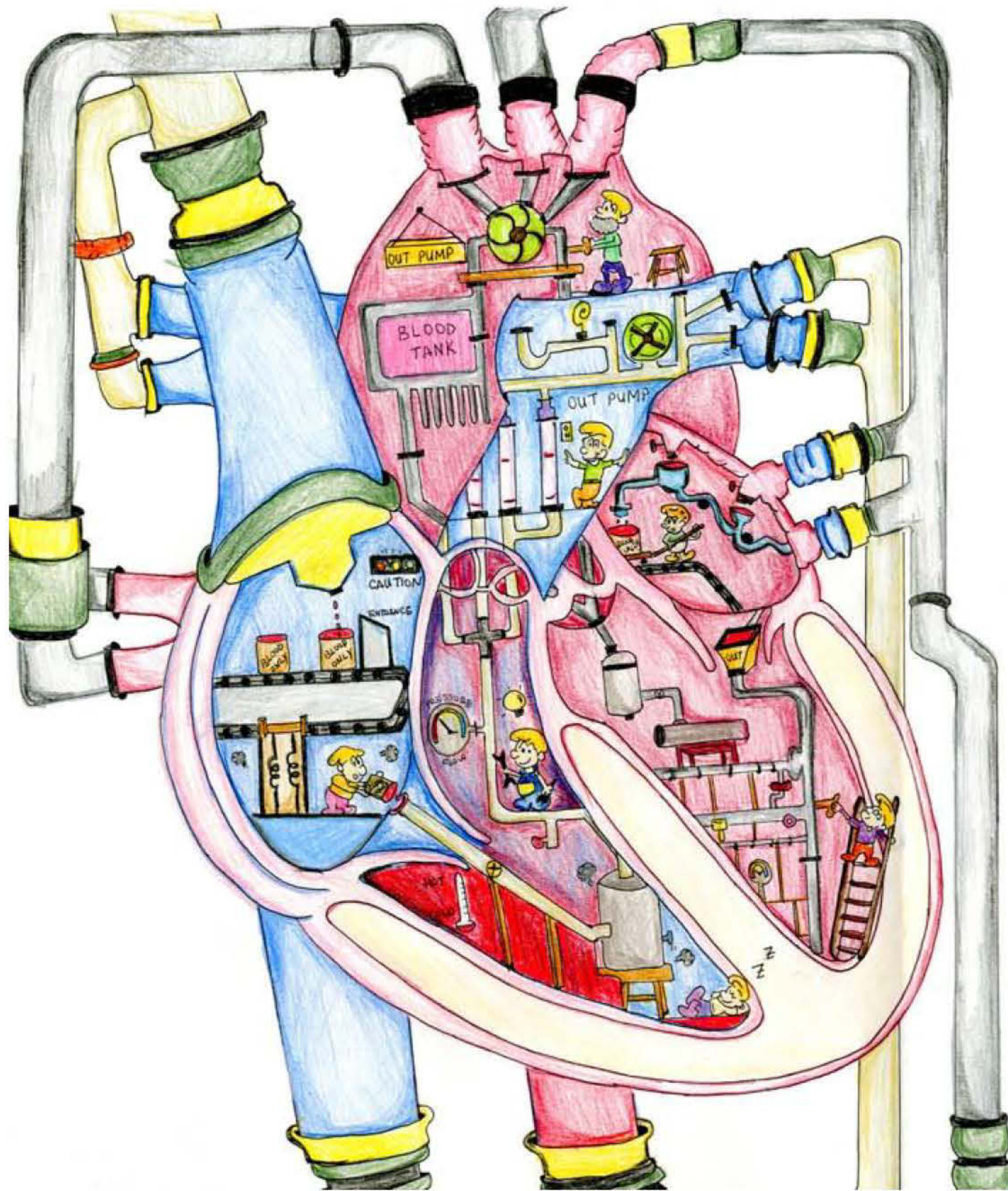


Drawing # 3  
Title Chameleon Astro  
Date Nov 20, 2009  
Scale n/a



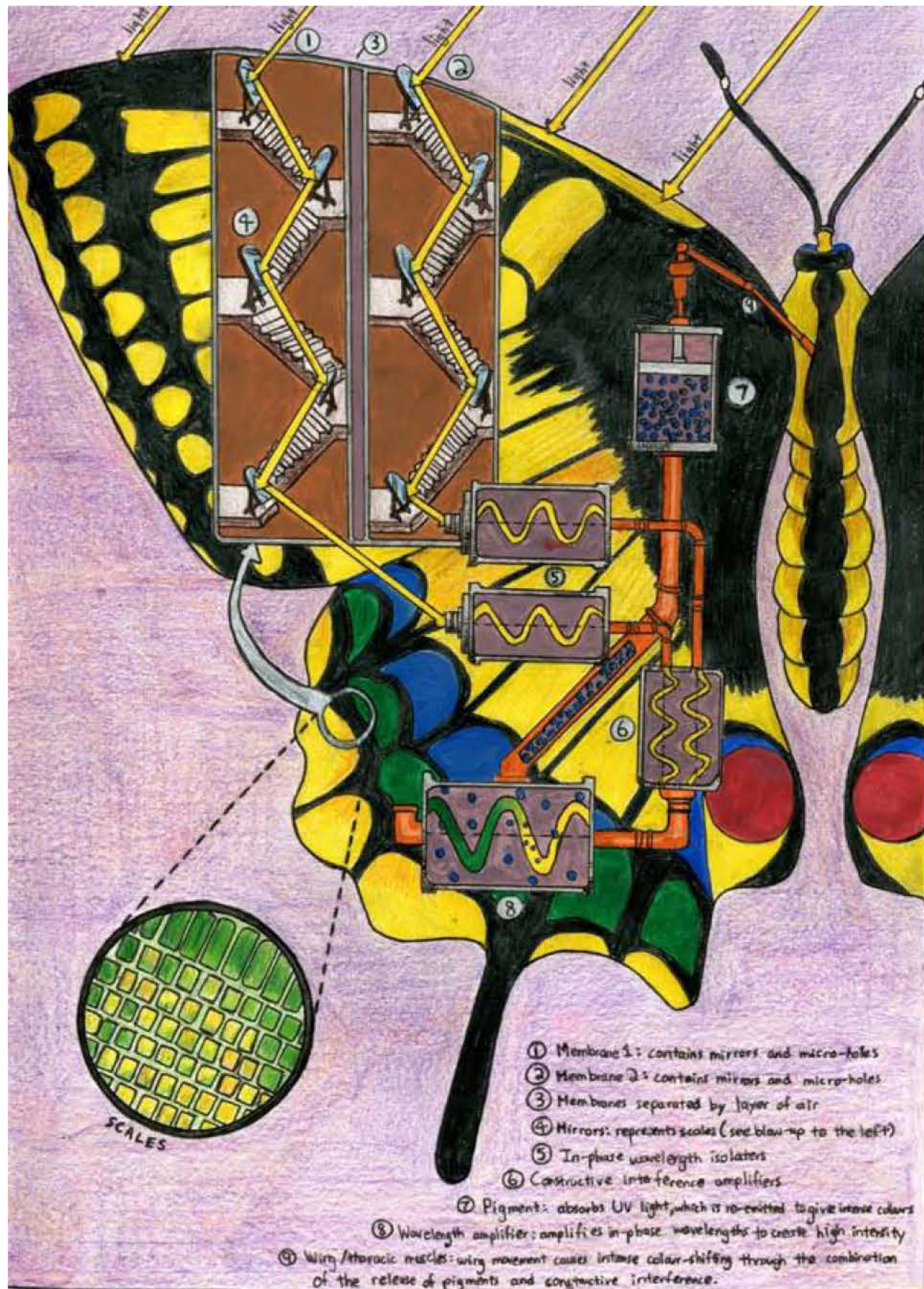




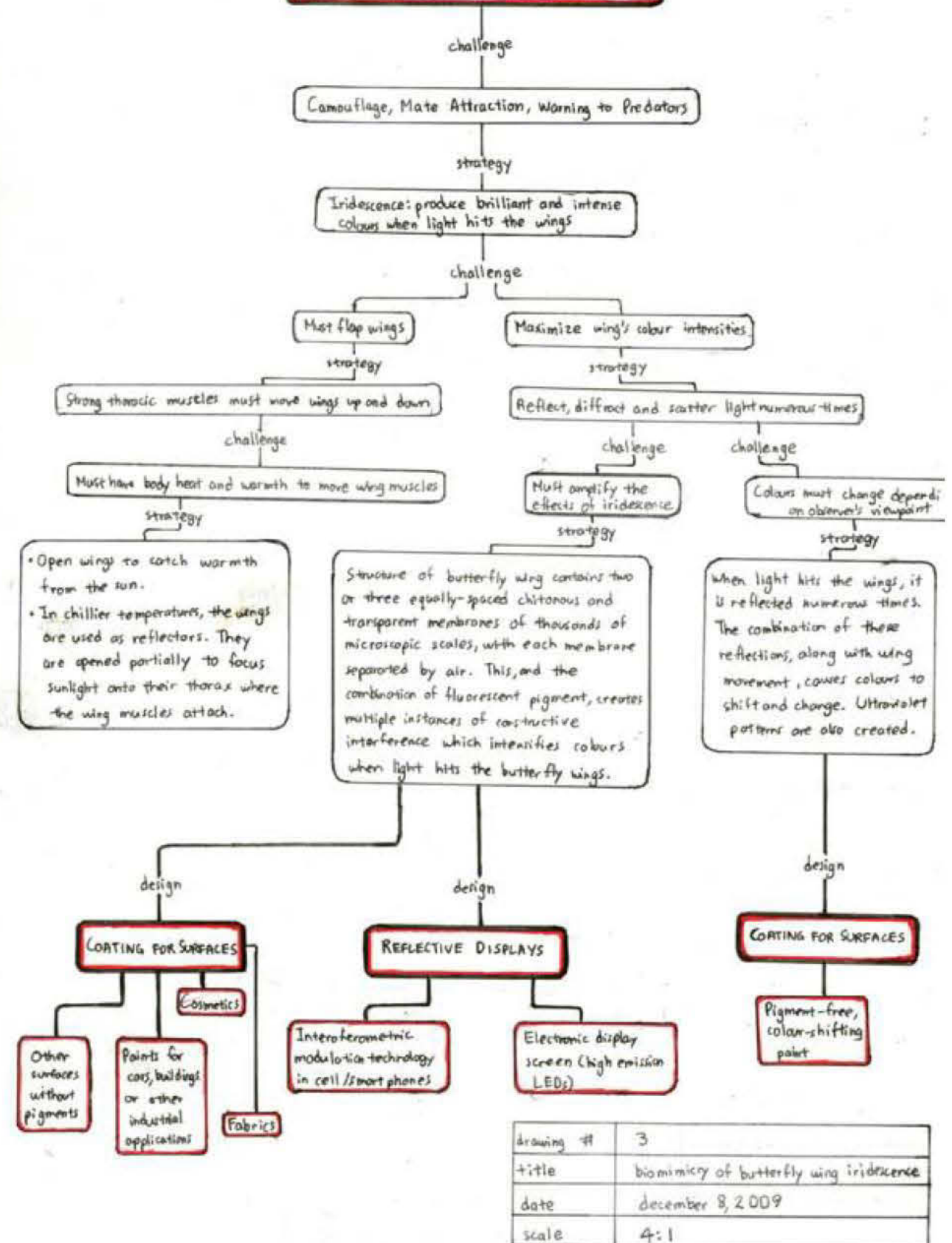


Drawing #	3
Title	Biomimicry -
Date	Dec 8, 20

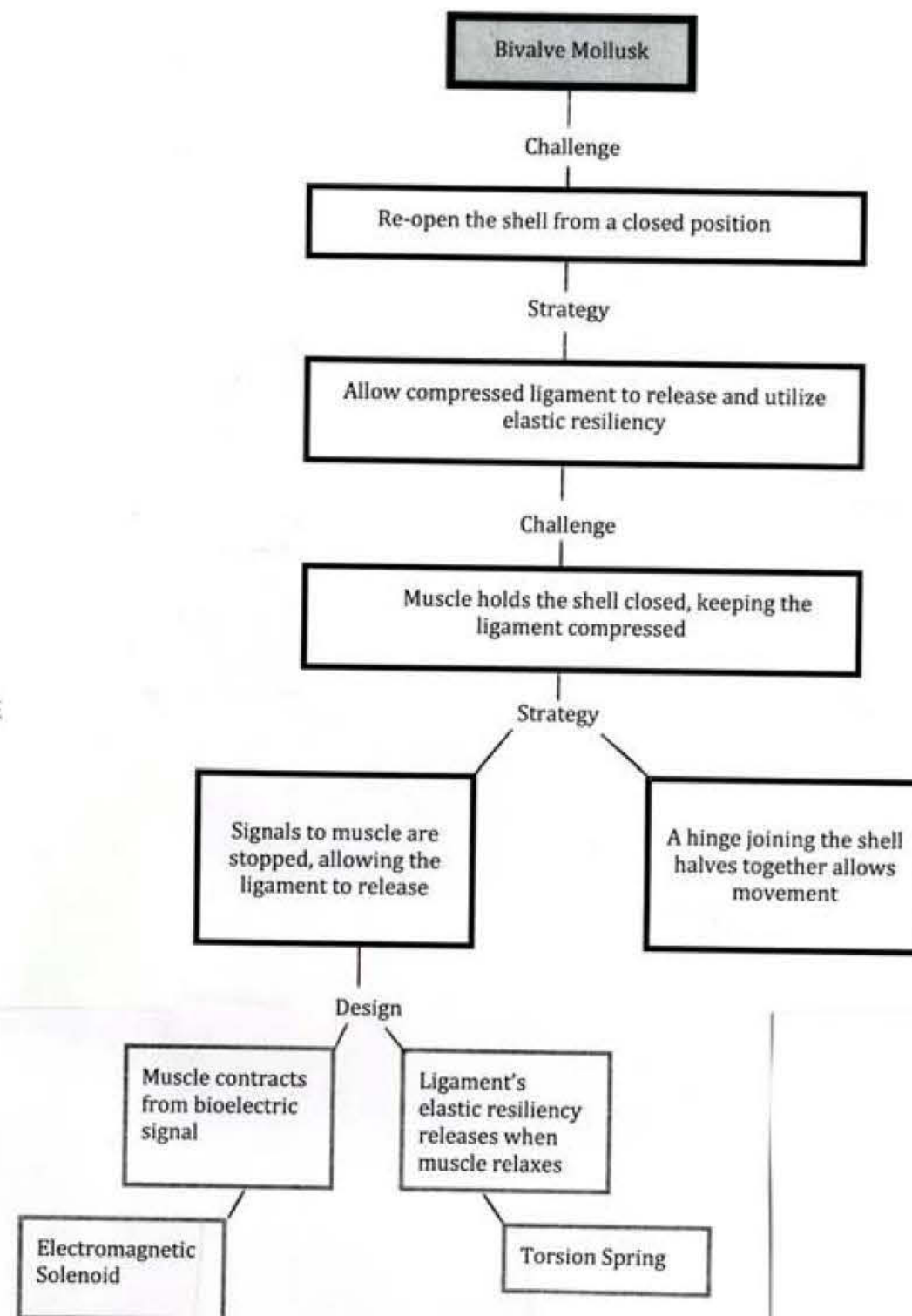
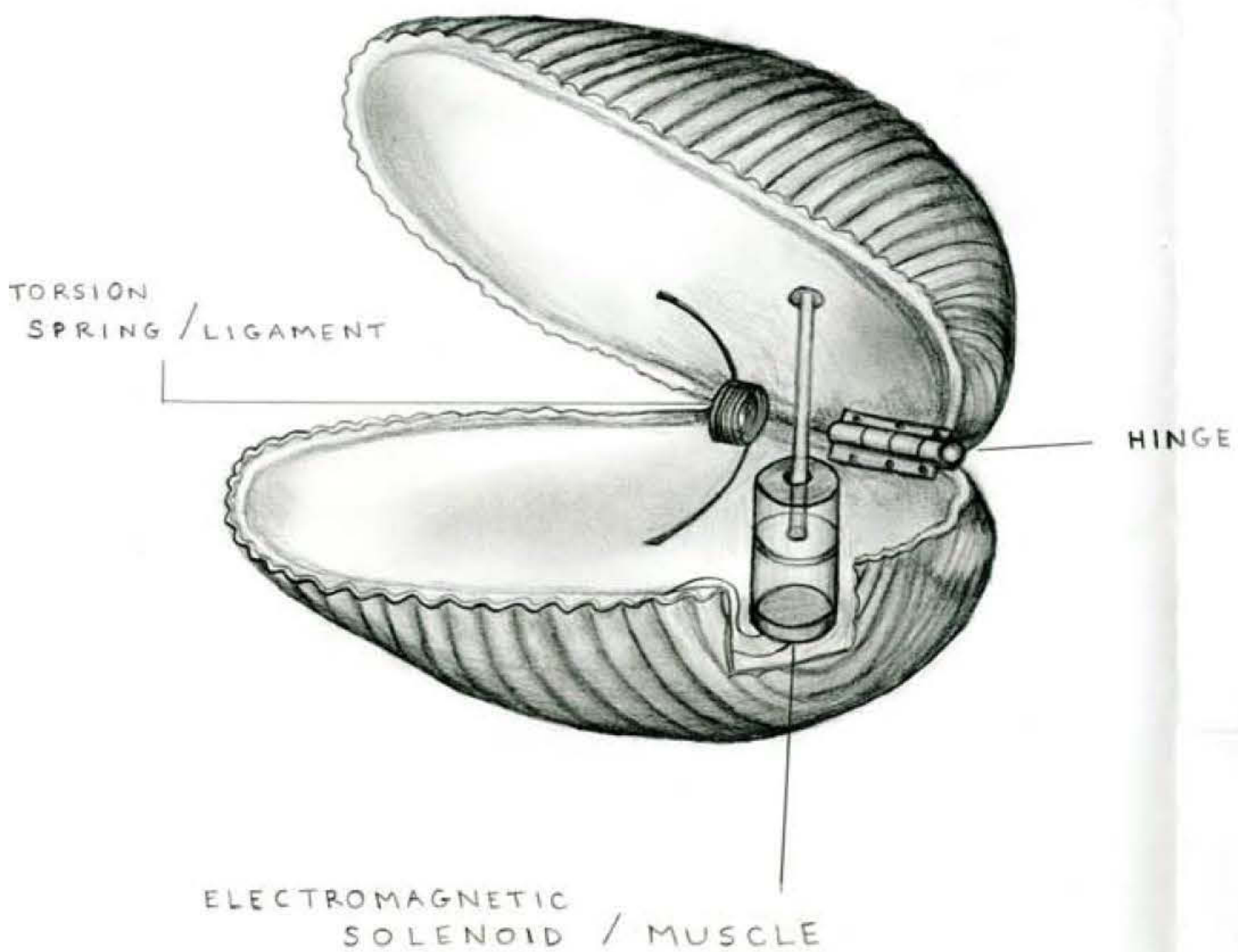




## AFRICAN SWALLOWTAIL BUTTERFLY

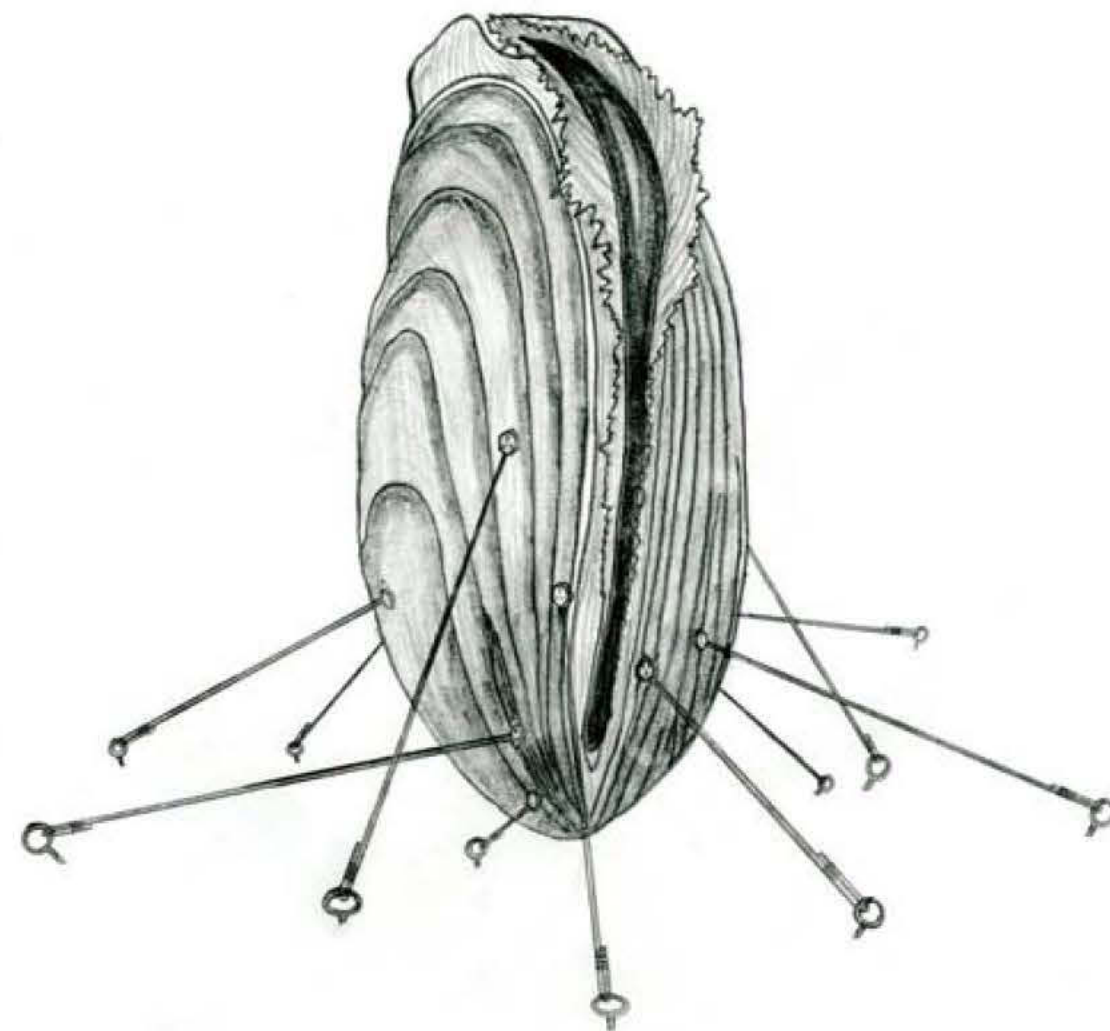
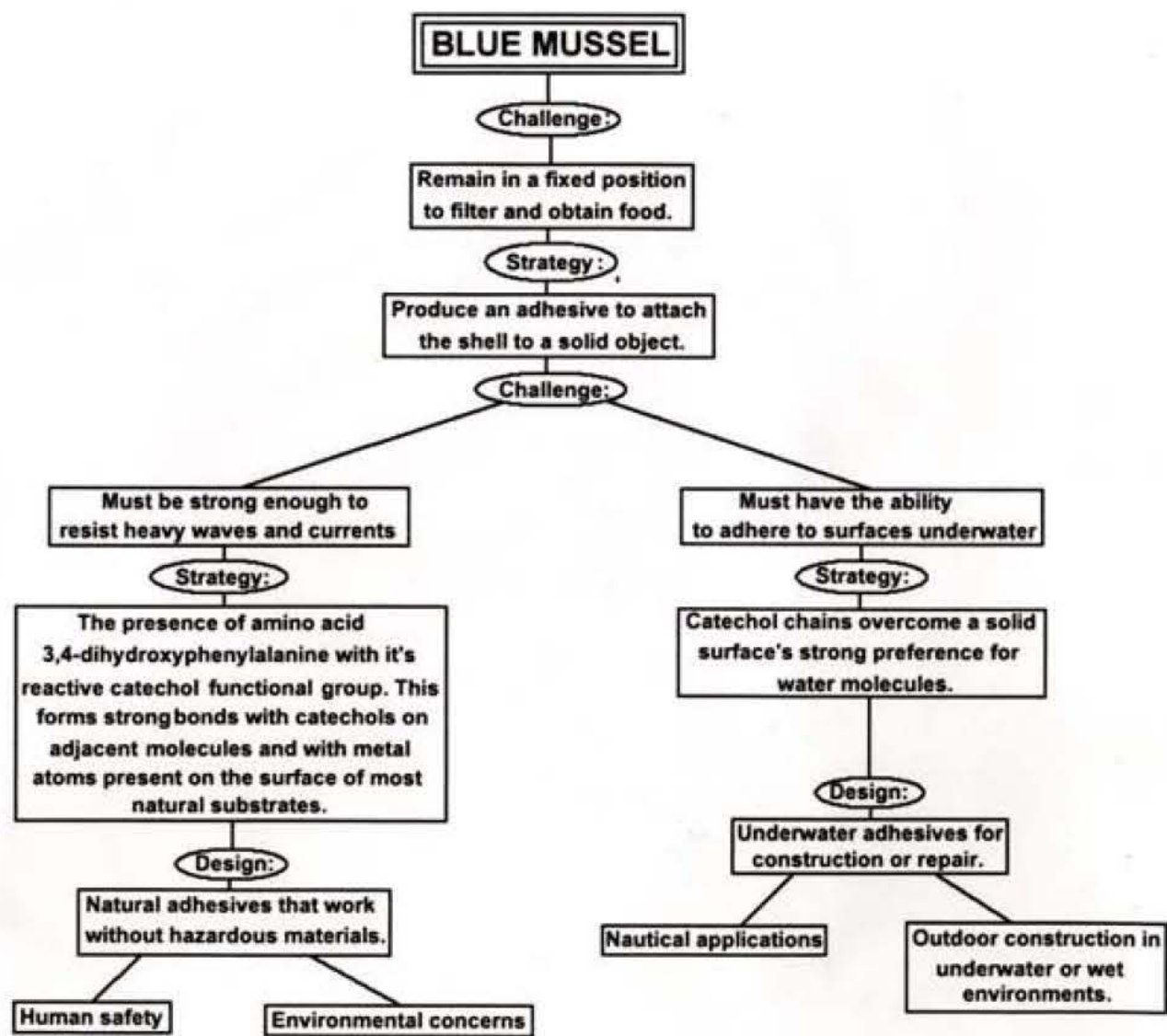






Drawing #	3
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Date	Dec. 4, 2009

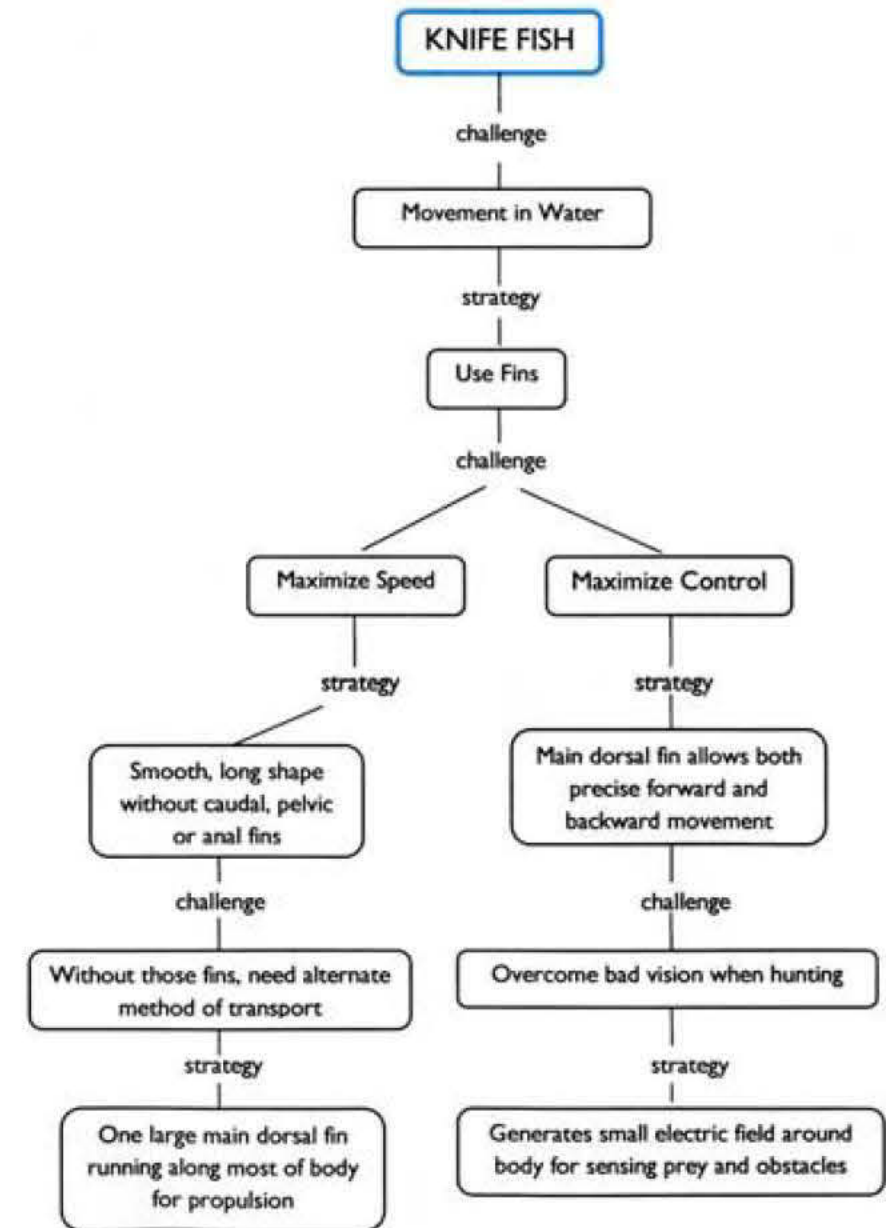
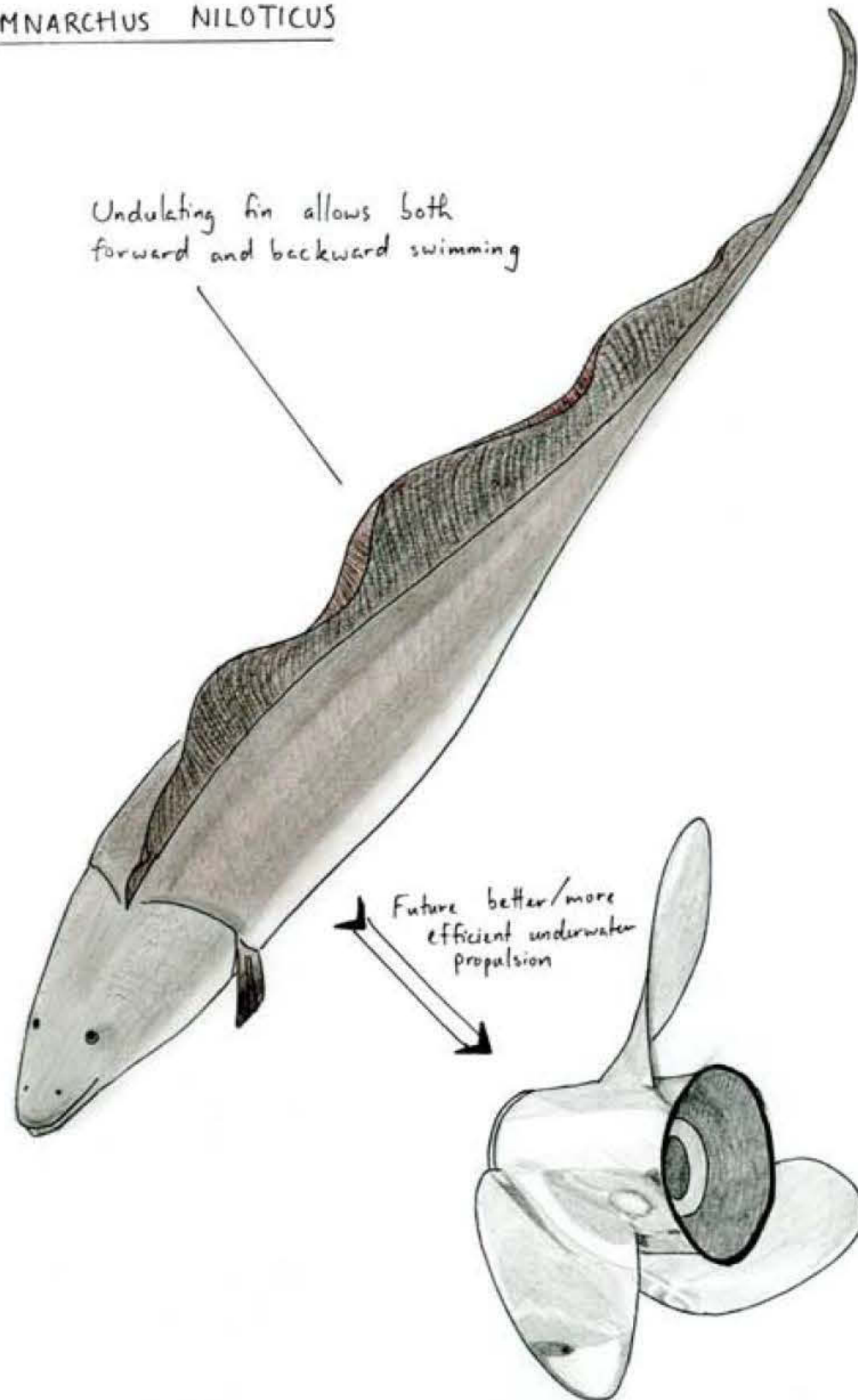




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DATE:	DEC
SCALE:	2:1

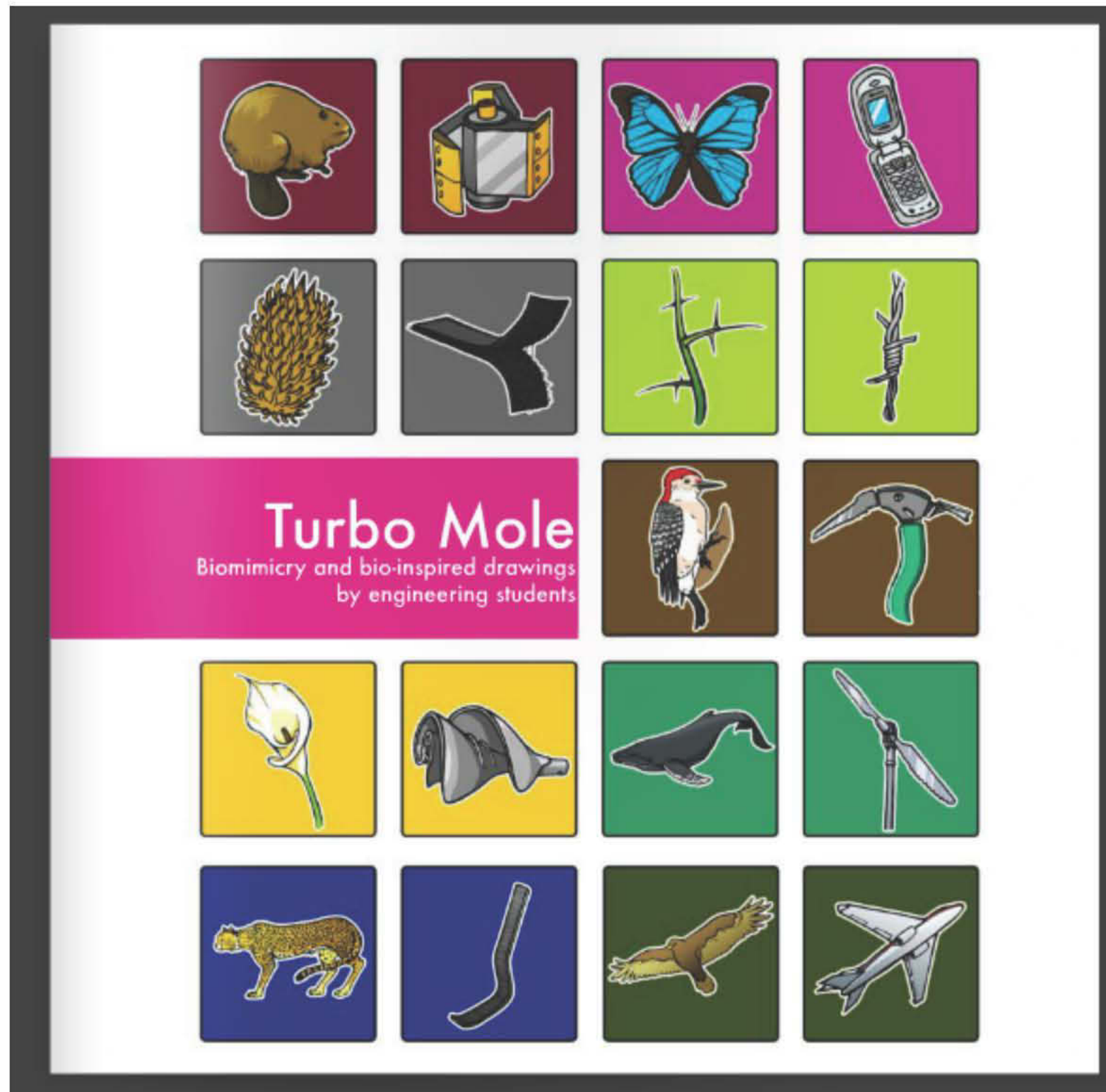


# GYMNARCHUS NILOTICUS



Drawing #	3
Title	Knife Fish
Date	December ,09
Scale	N/A





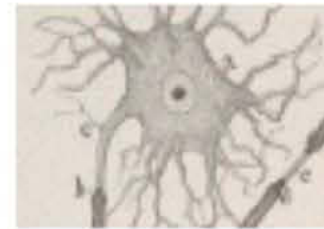
[https://issuu.com/eggermont/docs/bio\\_drawing\\_sample](https://issuu.com/eggermont/docs/bio_drawing_sample)



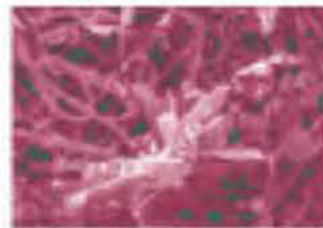


## Case Study: Our Material World: A Composition in Major and Minor Keys

Tom McKeag 8



People: Interview with  
Rick Dove 76



## Case Study: Oh, So Plastic!

Tom McKeag 8



People: Interview with  
Russell Kerschmann 86







tions such as Georgia Tech, CalTech and Harvard will be turning out young engineers who will be looking to NASA for opportunities to apply what they have learned. In order to get this topic elevated within NASA, we are working to include NID in the NASA Systems Engineering Handbook, a project that will benefit from George Stodur's INCOSE initiative.

On a more scientific level, I have been exploring the Phylogeny (evolution), Ontogeny (individual development) and Epigenesis (interaction with the environment) or POE model developed by Moshe Sipper and his colleagues as a way of organizing and making sense of natural process-

es. The Sipper group conceived of POE as forming the three dimensions of a natural systems process space, where each axis has unique characteristics that can also be viewed as different information processing modalities. Evolution builds a recording of historical events in DNA and this depends on errors called mutations. Ontogeny reads this evolutionary recording to create an individual living organism, but unlike evolution this is very fault intolerant, requiring mechanisms that avoid, detect and rapidly repair errors. Epigenesis involves the resulting animal, plant or microorganism's response and adaptation to environment changes, often through

some form of memory, such as the nervous and immune systems or structures (like bone) that develop through growth under stress. Much as the Cartesian system revolutionised the field of geometry, the POE model suggests opportunities for advancing engineering design in natural systems processes by exploring each axis as well as the interaction within the POE space.

*What is your favorite nature-inspired design of all time?*

The shining example of successful bio-inspired design in spacecraft engineering has to be the Ames Evolved Antenna ([http://www.nasa.gov/centers/ames/news/releases/2004/04\\_55AR.html](http://www.nasa.gov/centers/ames/news/releases/2004/04_55AR.html)), a project led by Jason Lohn (Carnegie Mellon University, Ames Research Center) that used a nature-inspired design process to meet a specific engineering requirement. A conventional antenna had already been designed for an Earth orbit mission called Space Technology 5 (ST5) mission. ST5 was intended to demonstrate new technologies, providing Jason an opportunity to propose an alternative novel antenna design created by using a genetic algorithm (phylogeny) that met all requirements but was different from anything seen before in both engineering and nature. Due to subsequent changes in the ST5 mission design, revised specifications were issued which could have seriously delayed the project because a conventional antenna would have no longer performed adequately. Hardware designs are often 'baked in' early in the design process and redesigns can be both expensive and time-consuming, but Jason was able to rap-

idly design and develop a revised antenna within a month, allowing the ST5 project to remain on track.

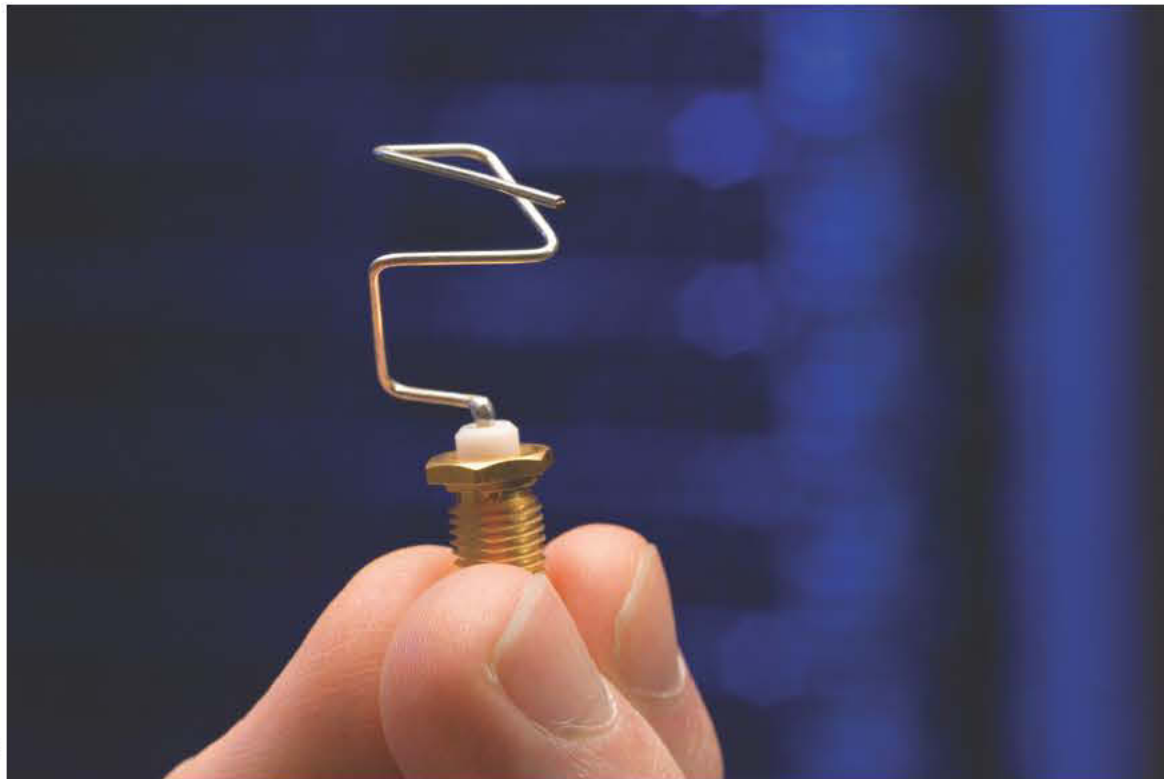
Although the goal was not to develop a better antenna but one that only met conventional design criteria, Jason Lohn's design process based on evolutionary algorithms was able to deliver solutions more rapidly than conventional approaches, which is critical when requirements change. The Ames Evolved Antenna has flown on two other missions that did not have a technology demonstration component: the LADEE lunar orbiter ([http://www.nasa.gov/mission\\_pages/ladee/main/](http://www.nasa.gov/mission_pages/ladee/main/)) and the IRIS mission ([http://www.nasa.gov/mission\\_pages/iris/index.html](http://www.nasa.gov/mission_pages/iris/index.html)). Jason co-founded the start-up X5 Systems (<http://www.x5systems.com/>) to commercialize his design method.

*What is the last book you enjoyed?*

*Consciousness: Creeping up on the Hard Problem*, by Jeffrey Gray.

*Whom do you admire? Why...*

That's a tough one: I have met many great people. I would say that out of the many the three that come to mind are my mentor, the late Dr. Guido Majno, Chairman of Pathology at the University of Massachusetts Medical School. If I hadn't by some stroke of chance early in my medical education attended one of Dr. Majno's lunchtime U. Mass lectures on the history of medicine, my career would have been radically different. Also, Apollo 17 Astronaut Jack Schmitt, who I worked with on the lunar dust project while I was Chief



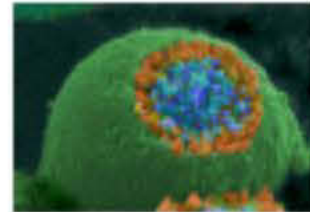
Ames Evolved Antenna

Photo: Ames Research Centre, NASA





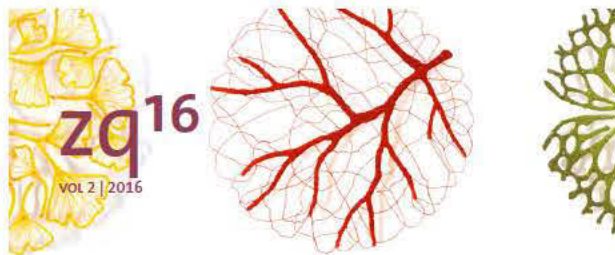
Boundless Curiosity: A Tribute to Steven Vogel  
Tom McKeag 8



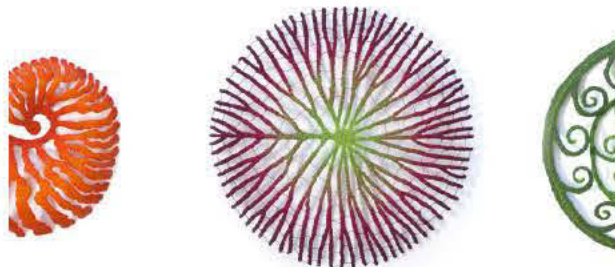
Article: When Success Fails  
Steven Vogel 18



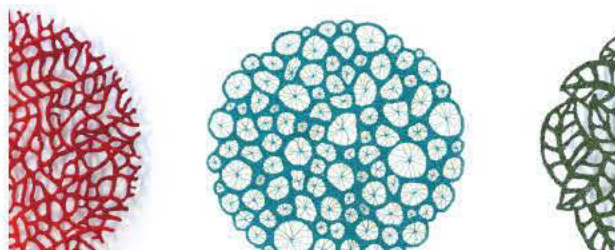
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Recognition



**Focus**

(Immediate Media)

**Science et vie kids**

(Mondadori Magazine, France)

**Scientific American**

(Nature Publishing Group)

**New Scientist**

(New Scientist)

**Inquire**

(Auto de Fe magazine Ltd)

**Braintainment**

(Panorama Media)

**Zygote Quarterly**  
(ZQ)



# DMA2013

Digital Magazine Awards

## Sectors

Children's  
Customer  
Fashion  
Food and Drink  
Film, TV and Entertainment  
Motoring  
Men's Lifestyle  
Women's Lifestyle  
Music  
News and Business  
**Science and Nature**  
Specialist  
Sport, Health and Fitness  
Travel  
Technology and Gadget  
Visual Arts

## Science and Nature Magazine of the Year

**Ask** (ePals Media)

**Australian Geographic** (Australian Geographic)

**BBC Focus Magazine** (Immediate Media Co)

**e-Science** (Faculty of Sciences, University of Adelaide)

**Max Planck Research** (PressMatrix GmbH)

**New Scientist** (New Scientist)

**Spektrum** (Spektrum)

**ZQ** (ZQ)

Click the images below to download finalist logos





# Science & Nature Magazine of the Year

In Association with Apazine

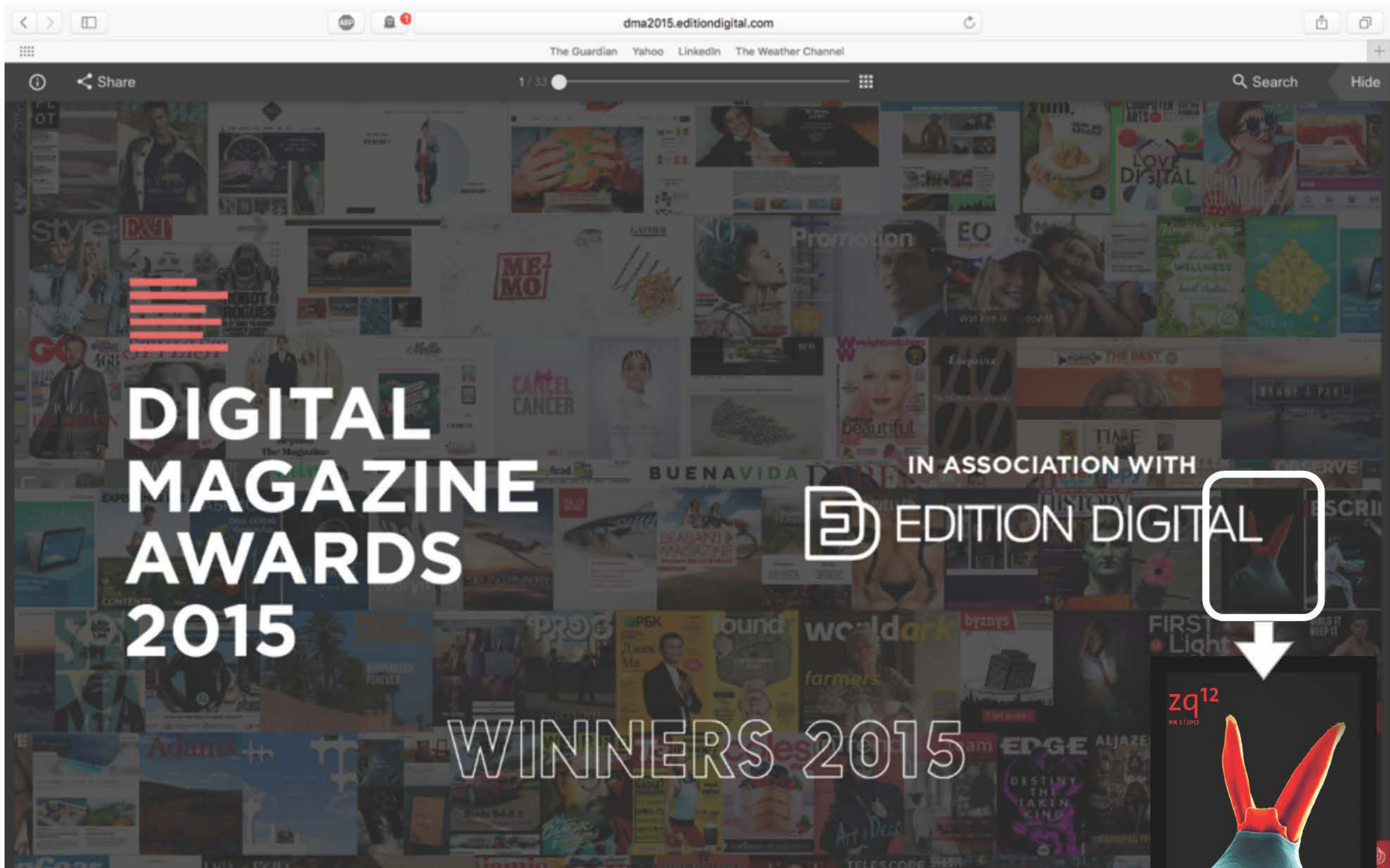
e-Science (Faculty of Sciences, University of Adelaide)  
Focus (Immediate Media Co)  
Kids Discover: Ecology (Joe Zeff Design)  
Lund University Research Magazine (Lund University)  
National Geographic Magazine (National Geographic Society)  
**ZQ (Zygote Quarterly)**

# Specialist Magazine of the Year

In Association with Apazine

BBC History (Immediate Media Co)  
e-Science (Faculty of Sciences, University of Adelaide)  
Edge (Future Plc)  
Flight Safety Australia (Civil Aviation Safety Authority - Australia (CASA))  
History Revealed (Immediate Media Co)  
Homes & London (Totality)  
Telescope Mag (Telescope Mag)  
The Write Life Magazine (The Write Lifestyle)  
TWM - The Watch Magazine (Watchfinder & Co.)  
WatchTime (WatchTime)







NOMINATED FOR  
BEST DIGITAL PUBLICATION

**Zygote Quarterly**  
ZQ

Marjan Eggermont, Designer, Publisher, Editor; Norbert Hoeller, Editor, Writer, Webmaster;  
Colin McDonald, Designer, Webmaster, Web Designer; Tom McKeag, Editor, Writer;  
Raul de Villafranca, Manuel Quiros, Tanya Lynne Sakamoto, Contributing Editors



Zygote Quarterly  
Biomimicry Summit and Education Forum (BSEF)  
Special Issue





GREAT LAKES  
BIOMIMICRY



#### **ZYGOTE MAGAZINE BSEF INTERVIEW**

Thank you so very much for answering our interview questions. Your insights are important to us and, with your colleagues' responses, will form the basis of our periodic assessments of the profession of bio-inspired design.

**Bio: (Program bio will be used unless one is added in this document)**

**Would you please tell us about?**

#### **THE SUMMIT**

- What are the key takeaways from your conference talk? How would you summarize your presentation?
- What impact do you hope/expect/intend your conference talk to have on your profession and/or others? How will it advance the field?
- What stood out at this conference and what did you learn?
- What is not clear to you and would like to learn or know more about
- Any circumstantial benefits? New collaborations? Interesting discussions during the breaks?
- Any action items after this conference? Things you will do, would like to do?

#### **OUR PROFESSION:**

- What are your impressions of the current state of bio-inspired design?  
What is working well for the current state of bio-inspired design?
- What do you see as the biggest challenges?

<http://zqjournal.org/>



# *Interview*

Peter Niewiarowski

Gecko

Photo: Pancholp, 2016 | Flickr cc



Dr. Peter Niewiarowski (<https://www.uakron.edu/biology/faculty-staff/detail.dot?identity=1201909>), Professor of Integrated Biosciences (IB) and Biology at the University of Akron (UA), is a Biomimicry Research and Innovation Center (BRIC) Principal Investigator. His appointments include Post-Doctoral Researcher, Savannah River Ecology Lab, University of Georgia, 1993-1995; UA Professor since 1995; and, Interim Director, UA Integrated Bioscience PhD Program, 2009-2012. His research includes projects in amphibian population biology, life history evolution and physiological ecology of lizards and gecko ecology and evolution,



Peter Niewiarowski

Photo of Peter Niewiarowski

especially as it relates to adhesion. Gecko adhesion research, in collaboration with the lab of Ali Dhinojwala, a UA polymer scientist and BRIC principal investigator, is the main focus of his current work, including biomimetic applications.

Peter teaches introductory and advanced levels within UA's Biology and IB programs. He developed courses including Advanced Ecology, Herpetology, Principles of Biology, Vertebrate Zoology, Tropical Vertebrate Biology, Communicating in Integrated Bioscience, Research in Integrated Bioscience, Theory and Foundations of Biomimicry, and Biomimicry Design.

Peter holds a BS in Biology, Marlboro College, Marlboro VT, 1984, and a PhD in Ecology and Evolutionary Biology, University of Pennsylvania, Philadelphia PA, 1992.


*What are your impressions of the current state of biomimicry/bio-inspired design?*

In my view, it is in a very exciting, generative phase. There is no shortage of activities and initiatives, formal and informal, academic and non-academic, which are popping up globally. Many are connected or are getting connected through dynamic knowledge and social networks that amplify potential impacts beyond local frames. I am daily struck by the intellectual and creative dissonance that emerges from so many diverse and widely distributed efforts in both the application and process of biomimicry. The dissonance is driven by enormous messiness, which is disconcerting to many people, but which is also a fundamental source of surprise and success. For a biologist, it is like going to a new place for the first time ... the excitement around the un-



Gecko | Photo: kevin1024, 2007 | Flickr cc





known and of discovery is visceral. It is great to be a part of this time in the development of the ideas and application of biomimicry.

*What do you see as the biggest challenges?*

I think the biggest challenges include finding ways to connect, sustain and deepen the diverse groups developing biomimicry across the globe. From my vantage point, I think we need more work across disciplinary lines in academic settings, and this will require courage, experiments and patience. There are many programs where two disciplines are brought together, like biomechanics and bioinformatics. Much rarer are platforms where the cultures, methods, and perspectives of 3 or 4 fields can be brought to bear collaboratively on problem definition, discovery, design and the application of biomimicry. In my view, expanding what is possible with biomimicry will require such exploration, integration and synthesis. Similarly, we should look for new ways to create paths that cross and become well-worn between academia, business and communities. Universities can lead both of these kinds of changes, but it is not work that universities are necessarily used to. Our collective here in northeast Ohio was built by partners that cross many of the lines noted above and we find the work difficult yet rewarding. Biomimicry as a practice would benefit from more experiments crossing these boundaries.

*How did the University of Akron Biomimicry Training Platform Get Started?*

Doug Paige (Associate Professor of Industrial Design at the Cleveland Institute of Art, [http://](http://www.cia.edu/academics/industrial-design/faculty/douglas-paige)

[www.cia.edu/academics/industrial-design/faculty/douglas-paige](http://www.cia.edu/academics/industrial-design/faculty/douglas-paige)) and I started collaborating in 2010 on combining biology and design as part of the University of Akron's Integrated Biosciences PhD program. Holly Harlan, founder of the Cleveland Entrepreneurs for Sustainability (E4S) network, encouraged us to attend a Biomimicry 3.8 Educators Workshop in San Francisco. When challenged to set ourselves a Big Hairy Audacious Goal, we decided to launch a sustainable PhD platform around biomimicry and collaboration that cuts across fields and programs. It was an idea that would have gone exactly nowhere without the collaboration of Tom Tyrell and Don Knechtges, two entrepreneurs who created Great Lakes Biomimicry (GLBio, <https://glbiomimicry.org/>), an organization focused on using biomimicry for regional economic development. GLBio connected us to industry, making the funding for biomimicry fellowships possible. The virtual Biomimicry Research and Innovation Center (BRIC, <http://uabiomimicry.org/about>) was launched in 2012 and recognized as a key initiative of the University of Akron's Achieving Distinction Strategic Investment Program (<http://www.uakron.edu/provost/achieving-distinction/2012-recipients.dot>). BRIC's success in winning university support depended on our corporate connections and economic development focus through collaboration with GLBio. Moreover, the focus of GLBio was to define a large scale sustainable platform for regional economic development through biomimicry. That vision was and continues to be a force driving biomimicry well beyond academic boundaries.



*What are the unique features of Biomimicry Training Platform?*

Although other institutions support PhD fellowships, they are typically associated with a single professor or grant initiative. The Biomimicry Training Platform is a research area of the University of Akron's Integrated Biosciences (IB, <http://www.uakron.edu/ib/>) interdisciplinary PhD program that draws students from a wide range of colleges, such as Arts and Sciences, Engineering, Polymer Science, School of Nursing, Arts and Sciences, Engineering, and Fine Arts. The platform started with three biomimicry Fellows in the fall of 2012 (<http://bioinspired.sinet.ca/content/uakron-phd-training-biomimicry-peter-h-niewiarowski>) and has since grown to 15 Biomimicry Fellows (<http://uabiomimicry.org/principal-investigators/fellows/>). In the same time, IB has grown to 50 PhD students in five research areas.

We admit students with a Bachelor's or Master's degree from any program. The current Fellows have backgrounds not only in biology but also arts, industrial design, engineering, mathematics, and computer science. They are supported by BRIC that draws faculty members from all colleges. BRIC is a fluid and dynamic organization – although focused on biomimicry, the members continue to work closely with colleagues in their individual faculties. Additional partners include the Cleveland Institute of Art, GLBio, and the professional design firms Balance Inc. (<http://www.balanceinc.com/>) and Nottingham Spirk (<http://nottinghamspirk.com/>).

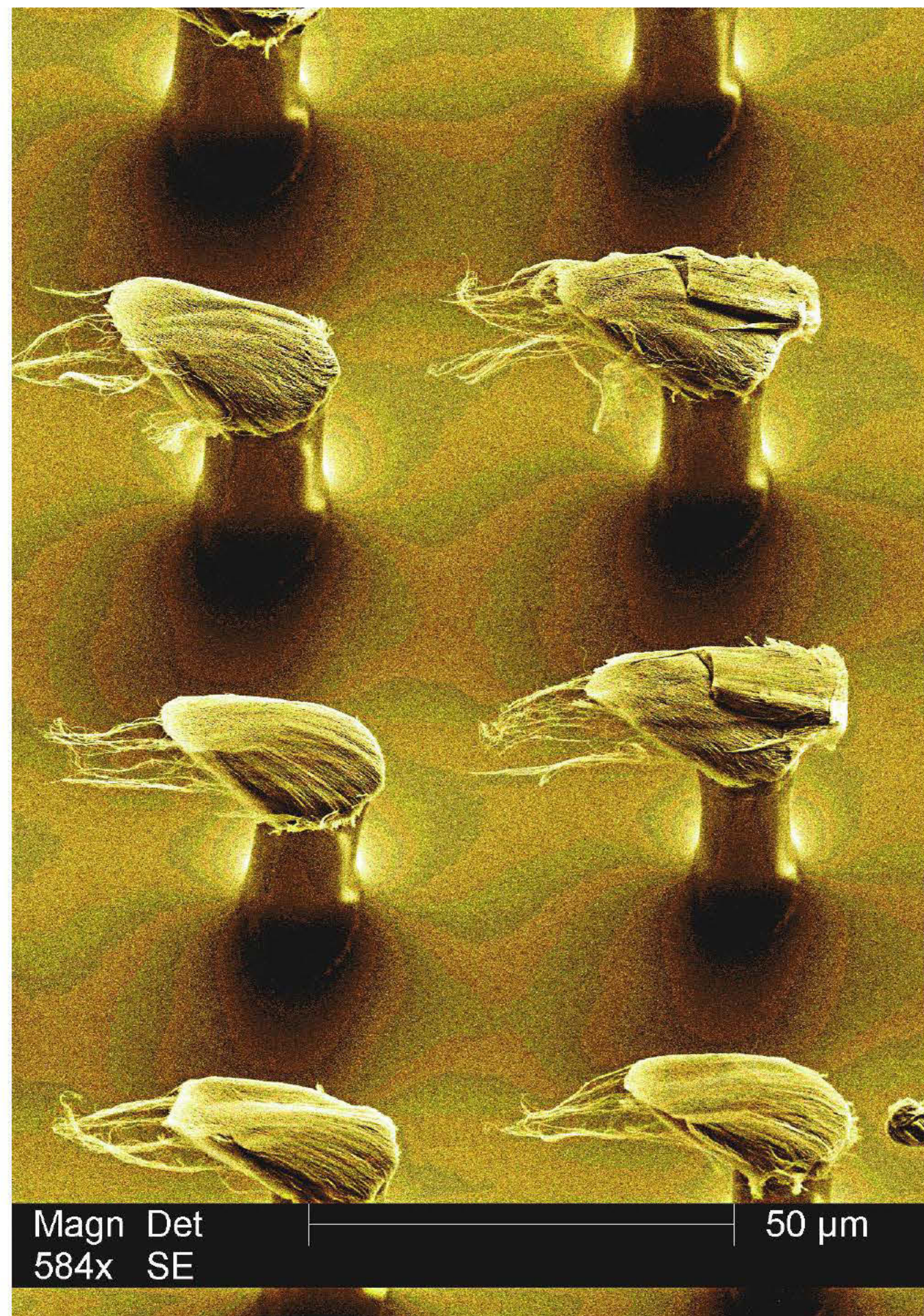
Lastly, Biomimicry Fellows are embedded in industry or schools, supported by five-year industry or foundation stipends of about \$130K ar-

ranged by BRIC and GLBio. Fellows funded by industry usually work with the company's R&D department, providing training in biomimicry as a tool, exploring specific initiatives, developing intellectual property, and in some cases working on new products and services. Six of the current Fellows are funded by foundations such as the Cleveland Zoological Society, Avon Lake Regional Waters and the Nord Family Foundation – they work with non-profits or help K-12 schools to develop curricula that broaden the STEM (Science, Technology, Engineering and Math) experience to include new approaches to innovation.

*What factors helped the initiative be successful?*

It is still too early to assess success, given the relative youth of the initiative compared to established PhD programs. We were fortunate to have strong support from U/Akron leadership from the beginning of the project. The partnership among U/Akron faculty, the Cleveland Institute of Art, GLBio and industry has been essential in building a collaborative that actively engages and nurtures networks.

U/Akron brought academics who understand the challenges of developing PhD programs as well as existing research connections with industry R&D departments. The Cleveland Institute of Art provides a focus on arts and design that complements the U/Akron capabilities. GLBio was started by two entrepreneurs who had a long history in running both small startups and large companies. GLBio had built extensive networks of regional corporate leaders interested in economic development, innovation and sustainability – invaluable in identifying suitable targets for the initial proof of concept. The full im-



This image is a colored versions of an SEM image of submicron hierarchical structures comprised of polymer pillars with transferred vertical carbon nanotubes fabricated using several lithographic steps. These are further tested and employed as novel and advanced nano-structures to mimic super adhesive properties of the gecko-foot. | Photo: Engineering at

Cambridge, 2012 | Flickr cc



pact of BRIC, especially beyond the boundaries of the University, cannot be appreciated outside of its deep collaboration with GLBio. Industry partners such as Partner Hannifin, Sherwin Williams, GOJO Industries, Lubrizol, Bendix, Goodyear, Kimberly-Clark, and Nottingham Spirk help ground the Fellows' research.

Lastly, BRIC has been able to build a critical mass of local expertise that also has global reach. In spite of the importance of digital communications, face-to-face interactions are still essential for effective interdisciplinary collaboration.

*What insights have you developed since founding BRIC?*

Interdisciplinary collaboration sounds easy but requires considerable and constant effort if it is going to be repeatable and scalable. Like any complex system, it involves building a network that enables information flows, interactions and creating new capacity.

All parties need to feel that they are getting value from the interaction. BRIC allows industry personnel to learn biomimicry concepts, explore how they can incorporate biomimicry at different scales into different departments, and experiment on specific projects. The value for Fellows tends to be more diverse. Some want to make an impact beyond building knowledge in their field or are attracted by the creative aspects of making ideas real. Others see collaboration as a way to identify gaps in current knowledge, increasing the breadth and depth of their understanding. The process of developing practical applications by creating and then testing models is consistent with how academics work.

Lastly, biomimicry is more than knowledge transfer – often the knowledge is either not available or hard to apply. Success frequently involves negotiating a common understanding across fields. Soft skills in social interaction and confidence combined with humility are as important as specific expertise – key relationships are tested regularly. It is crucial to create a 'space' that encompasses the important knowledge fields and ideally enhances all of them.

*What results have you seen so far?*

The first cohort of three Fellows (Daphne Fecheyr-Lippens, Bor-Kai Hsiung, and Emily Kennedy) are now in their fourth year. All have vastly different backgrounds but are deeply committed to biomimicry. They are truly the heroes and pioneers, dealing with the enormous challenges of dealing with the cultures of a university graduate program and industry R&D. They take great pride in how the initiative has grown around them. They have shown the value of taking ownership and being empowered to drive change by engaging in the real world.

Industry results depend heavily on company leadership, expectations and dynamics. Emily Kennedy has worked with multiple R&D departments at GOJO (<https://www.gojo.com/>) to improve sustainability, reduce carbon footprint and develop new ways of delivering products, leading to the filing of six patents. I expect that six or so Fellows will be delivering similar results over the next few years.



Gecko

Photo: Pancholp, 2012 | Flickr cc

*What opportunities do you see in the future?*

Opportunities: really, imagination is the only limit. Most exciting, in my opinion, are opportunities for diverse partnerships to drive formal R&D of methods for the field of biomimicry, and for getting biomimicry thinking into school curriculums at early ages.

*What is your favorite interdisciplinary work of all time?*

A book: *On Growth and Form* by D'Arcy W. Thompson. Cliché, I know.

*What is the last book you enjoyed?*

*The systems view of life: A unifying vision* by Fritjof Capra

*Whom do you admire? Why...*

People that pursue their dreams with passion, but never at the expense of others. Because that's a big part of what improves our world.

*If you could choose another profession or role, who/what would you be?*

Never even think about that; seems like a distraction to consider it.

*What is your idea of perfect happiness?*

It seems like an odd question. What I can say is I would be happier if I had a little more time for play, family and friends and a little more money to travel to faraway places I have yet to see. ✕







**“The trouble is that once you see it, you can't  
unsee it.**

**And once you've seen it, keeping  
quiet, saying nothing, becomes as political an  
act as speaking out.**

**There's no innocence.**

**Either way, you're accountable.”**

**- Arundhati Roy**







Thank you